UNSW
THE UNIVERSITY OF NEW SOUTH WALES

9b. Vision and Language Reasoning

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Goal

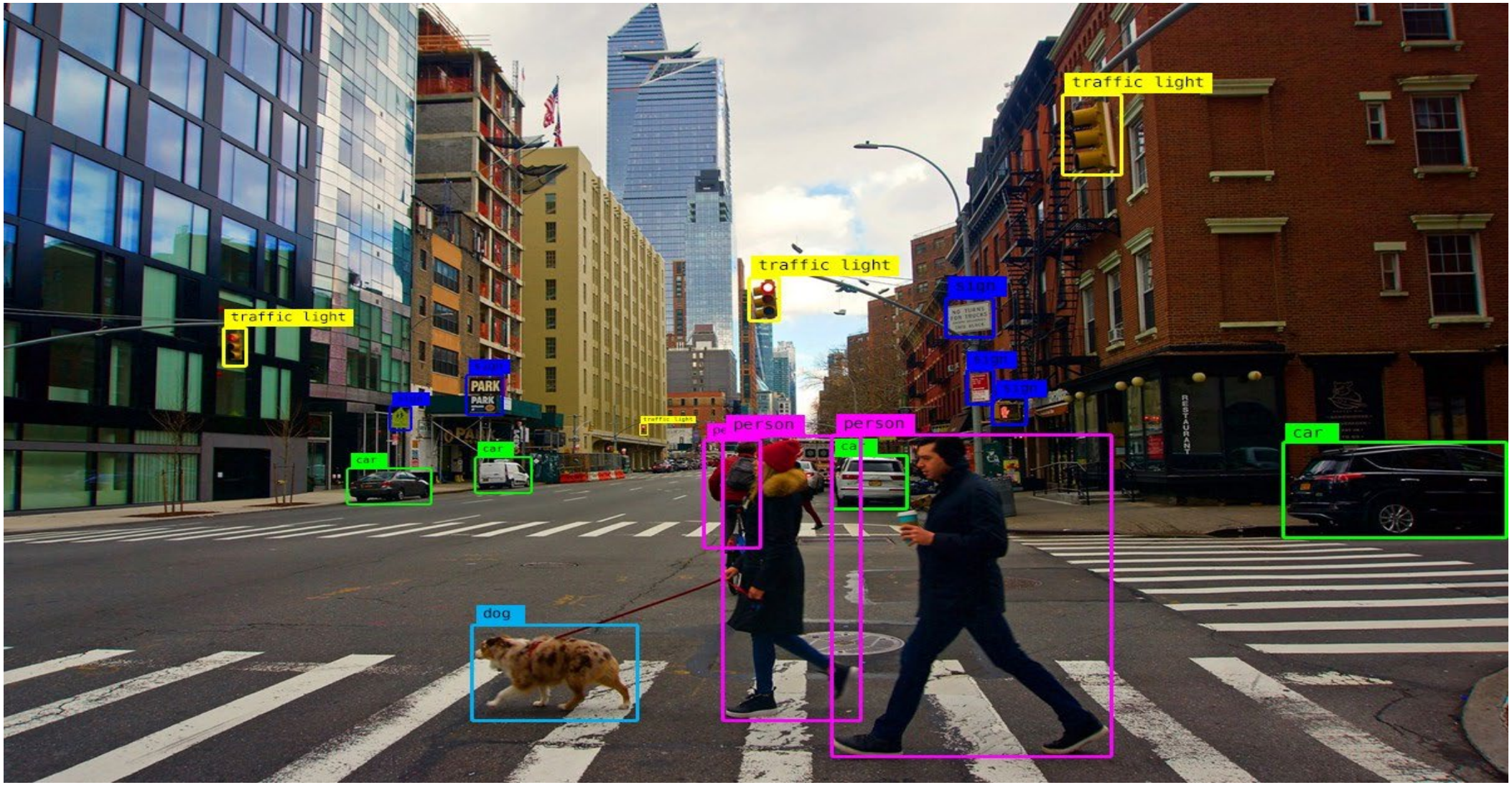
- To motivate the need for “Computer Vision + Natural Language Processing”
- After the talk, everyone can confidently say: “yeah, I know various tasks at the intersection of computer vision and natural language processing”
- Focus on high-level overview, not technical details
- Focus on static images, not videos (although they are easy to translate to videos)
- Focus on selective set of papers for various tasks, not a comprehensive literature review

Agenda

- Computer Vision
- Natural Language Processing
- Computer Vision + Natural Language Processing
- Building Blocks
  - Convolutional Neural Networks (CNNs)
  - Recurrent Neural Networks (RNNs)
  - Attention Mechanism
- Encoder-Decoder Framework
- Image Captioning
- Visual Question Answering (VQA)
- Visual Dialog (VisDial)
- Vision-Language Navigation (VLN)
- Visual Grounding
- Summary

Computer Vision

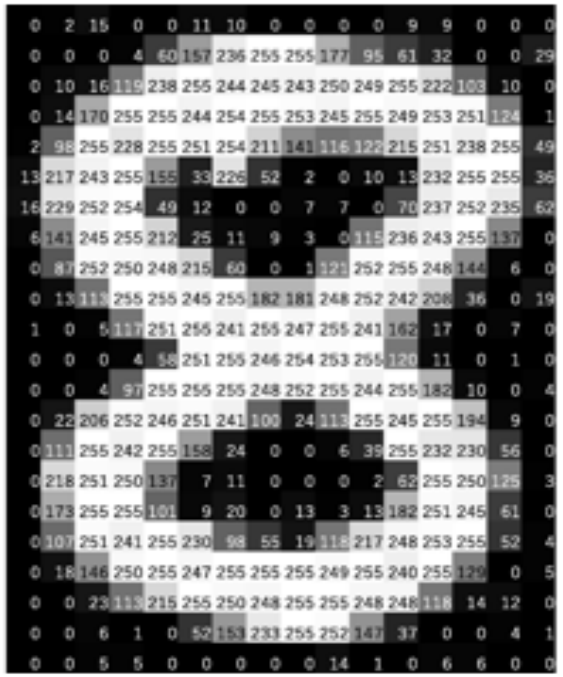
- Enabling machines to process, represent, understand, and generate visual data



Source: Computer Vision in Practice. https://levelup.gitconnected.com/deployment-computer-vision-in-practice-99b7bbb6aa7c

How computers see images?

- A matrix of numbers



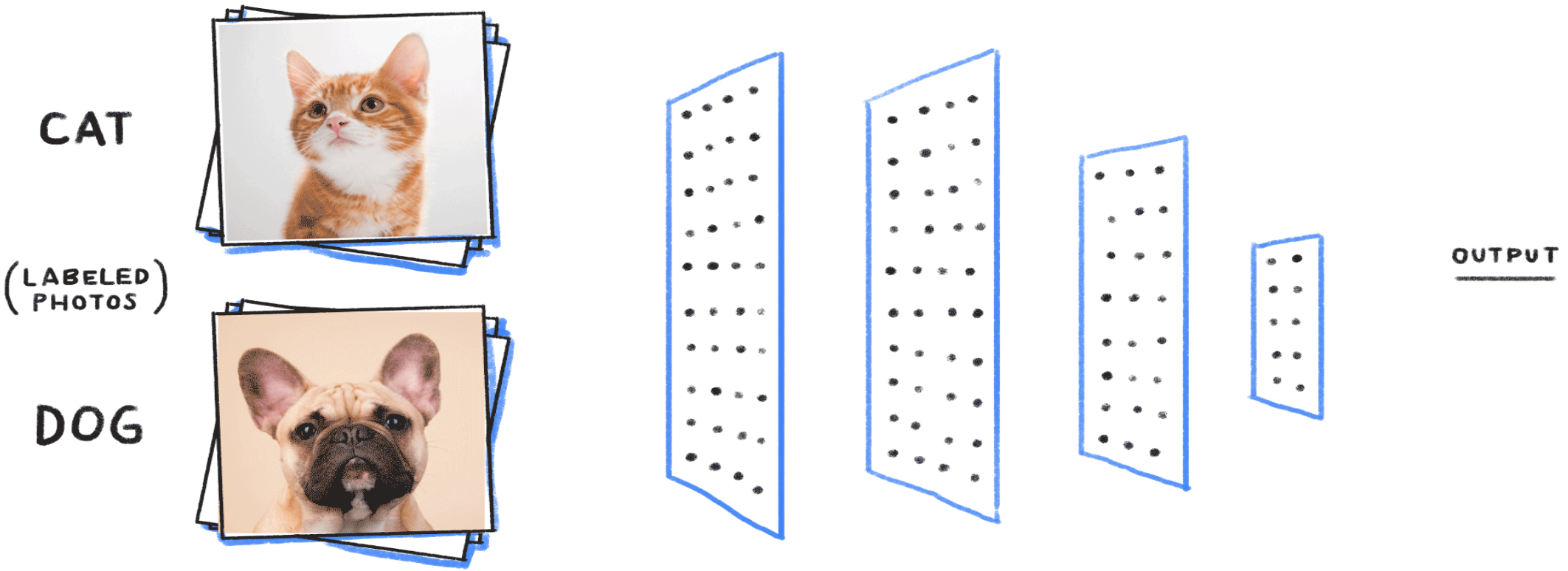
What Computer Sees

```
  0   2  15   0   0  11  10   0   0   0   0   9   9   0   0   0
  0   0   0   4  60 157 236 255 255 177  95  61  32   0   0  29
  0  10  16 119 238 255 244 245 243 250 249 255 222 103  10   0
  0  14 170 255 255 244 254 255 253 245 255 249 253 251 124   1
  2  98 255 228 255 251 254 211 141 116 122 215 251 238 255  49
 13 217 243 255 155  33 226  52   2   0  10  13 232 255 255  36
 16 229 252 254  49  12   0   0   7   7   0  70 237 252 235  62
  6 141 245 255 212  25  11   9   3   0 115 236 243 255 137   0
  0  87 252 250 248 215  60   0   1 121 252 255 248 144   6   0
  0  13 113 255 255 245 255 182 181 248 252 242 208  36   0  19
  1   0   5 117 251 255 241 255 247 255 241 162  17   0   7   0
  0   0   0   4  58 251 255 246 254 253 255 120  11   0   1   0
  0   0   4  97 255 255 255 248 252 255 244 255 182  10   0   4
  0  22 206 252 246 251 241 100  24 113 255 245 255 194   9   0
  0 111 255 242 255 158  24   0   0   6  39 255 232 230  56   0
  0 218 251 250 137   7  11   0   0   0   2  62 255 250 125   3
  0 173 255 255 101   9  20   0  13   3  13 182 251 245  61   0
  0 107 251 241 255 230  98  55  19 118 217 248 253 255  52   4
  0  18 146 250 255 247 255 255 255 249 255 240 255 129   0   5
  0   0  23 113 215 255 250 248 255 255 248 248 118  14  12   0
  0   0   6   1   0  52 153 233 255 252 147  37   0   0   4   1
  0   0   5   5   0   0   0   0   0  14   1   0   6   6   0   0
```


Source: https://medium.com/analytics-vidhya/cnn-series-part-1-how-do-computers-see-images-32462a0b33ca

CV Applications

- Image Classification



Source: Medium: Introduction to CNN & Image Classification Using CNN in PyTorch. https://medium.com/swlh/introduction-to-cnn-image-classification-using-cnn-in-pytorch-11eefae6d83c

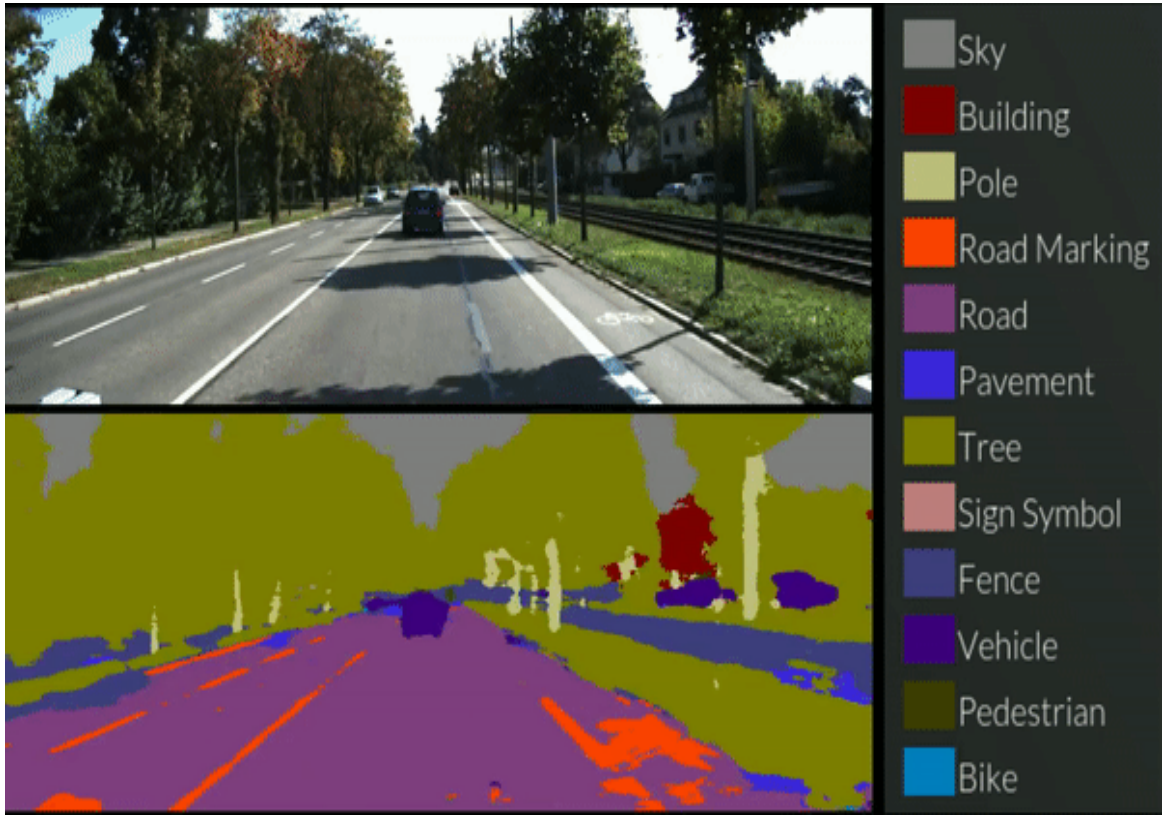
CV Applications

- Object Detection

Image Credit: Google Cloud Vision API. https://cloud.google.com/vision/docs/object-localizer

CV Applications

- Segmentation



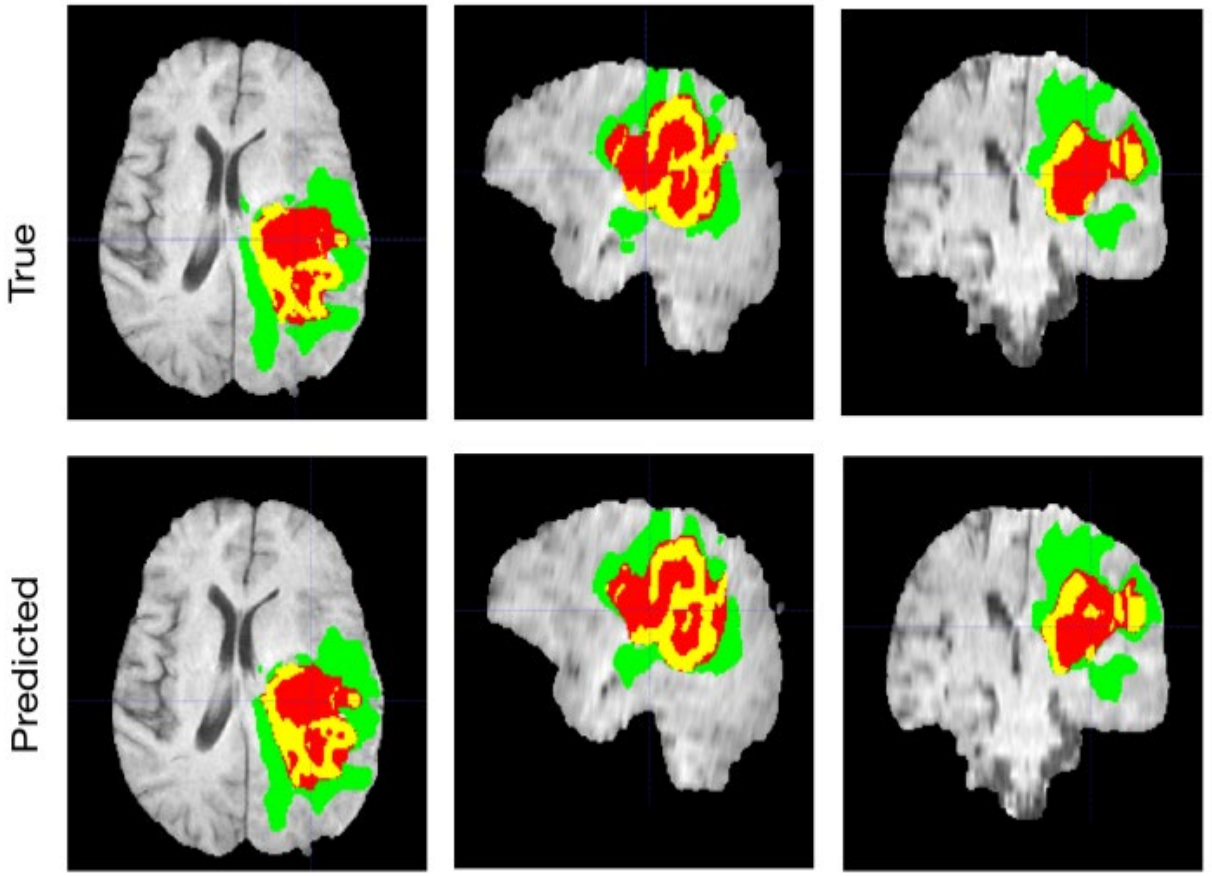


Image Credit: Analytics Vidhya: Introduction to Semantic Image Segmentation. https://medium.com/analytics-vidhya/introduction-to-semantic-image-segmentation-856cda5e5de8
Nvidia AI: Automatically segmenting brain tumours with AI. https://developer.nvidia.com/blog/automatically-segmenting-brain-tumors-with-ai/

Natural Language Processing

- Enabling machines to process, represent, understand, and generate languages

In fact, the Chinese NORP market has the three CARDINAL most influential names of the retail and tech space – Alibaba GPE , Baidu ORG , and Tencent PERSON (collectively touted as BAT ORG), and is betting big in the global AI GPE in retail industry space . The three CARDINAL giants which are claimed to have a cut-throat competition with the U.S. GPE (in terms of resources and capital) are positioning themselves to become the 'future AI PERSON platforms'. The trio is also expanding in other Asian NORP countries and investing heavily in the U.S. GPE based AI GPE startups to leverage the power of AI GPE . Backed by such powerful initiatives and presence of these conglomerates, the market in APAC AI is forecast to be the fastest-growing one CARDINAL , with an anticipated CAGR PERSON of 45% PERCENT over 2018 - 2024 DATE .

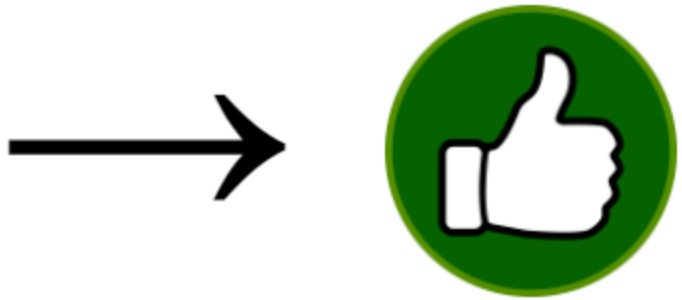
To further elaborate on the geographical trends, North America LOC has procured more than 50% PERCENT of the global share in 2017 DATE and has been leading the regional landscape of AI GPE in the retail market. The U.S. GPE has a significant credit in the regional trends with over 65% PERCENT of investments (including M&As, private equity, and venture capital) in artificial intelligence technology. Additionally, the region is a huge hub for startups in tandem with the presence of tech titans, such as Google ORG , IBM ORG , and Microsoft ORG .

Source: Hugging Face. https://twitter.com/huggingface/status/1230870653194121216

NLP Applications

- Text Understanding

"I love this movie.
I've seen it many times
and it's still awesome."

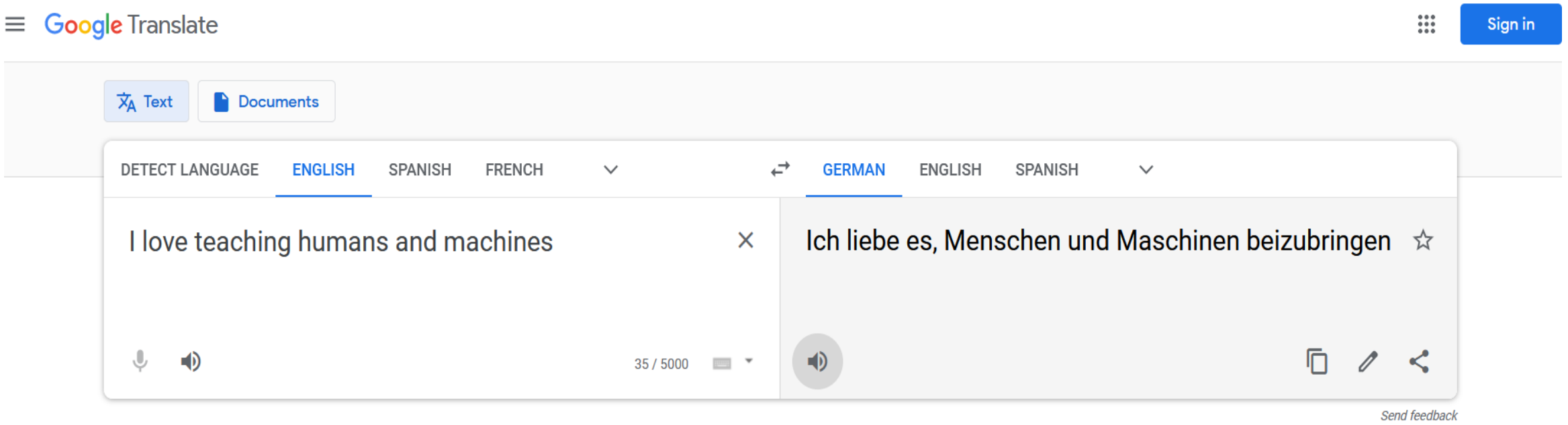


"This movie is bad.
I don't like it it all.
It's terrible."

Image Credit: Sentiment Analysis. https://colab.research.google.com/github/shangeth/Google-ML-Academy/blob/master/2-Deep-Neural-Networks/2_9_ANN_Natural_Language_Processing.ipynb

NLP Applications

- Machine Translation



NLP Applications

- Question Answering/Comprehension

Passage Sentence

In meteorology, precipitation is any product of the condensation of atmospheric water vapor that falls under gravity.

Question

What causes precipitation to fall?

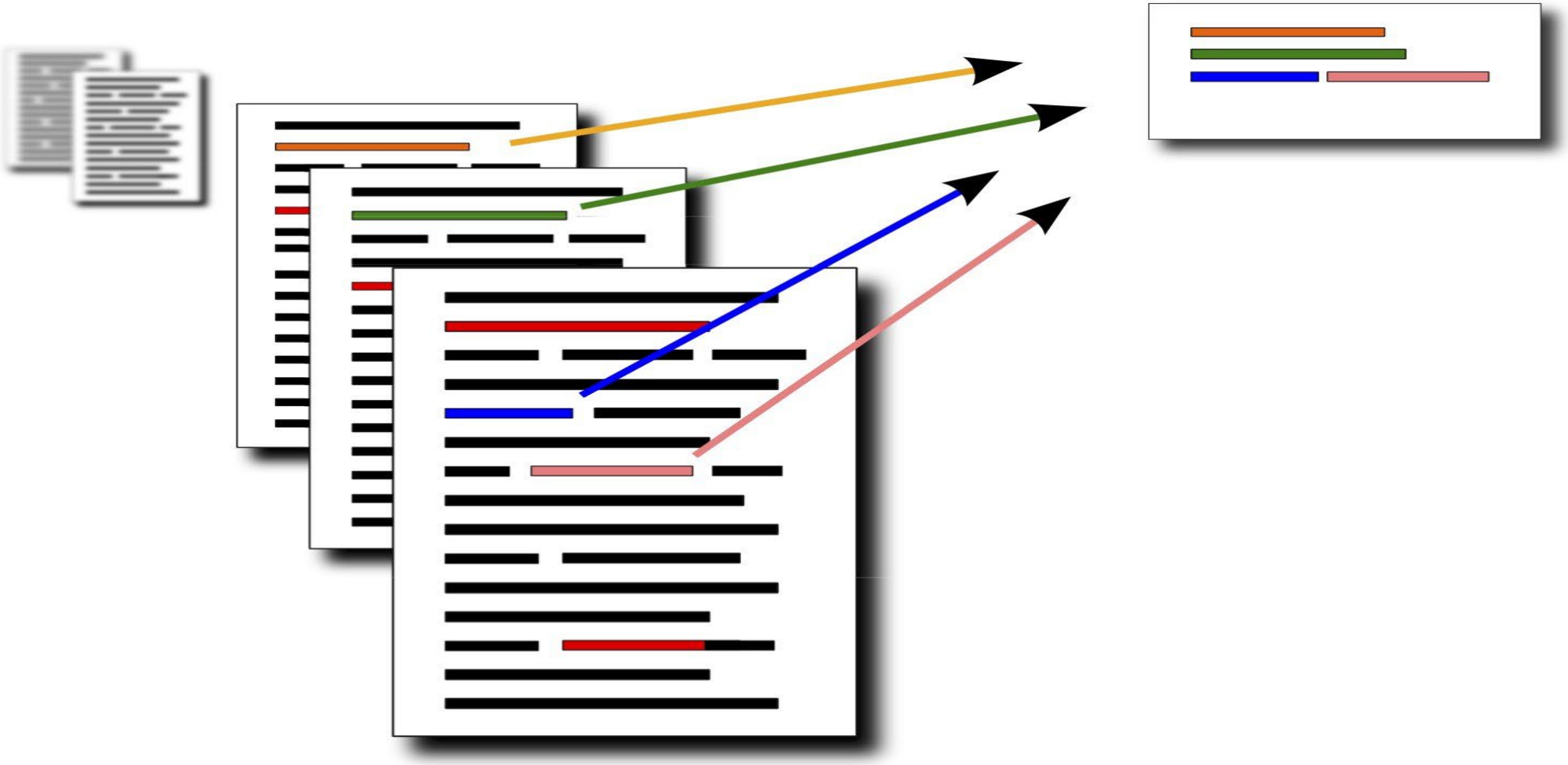
Answer Candidate

gravity

Source: The Stanford Question Answering Dataset (SQUAD). https://rajpurkar.github.io/mlx/qa-and-squad/

NLP Applications

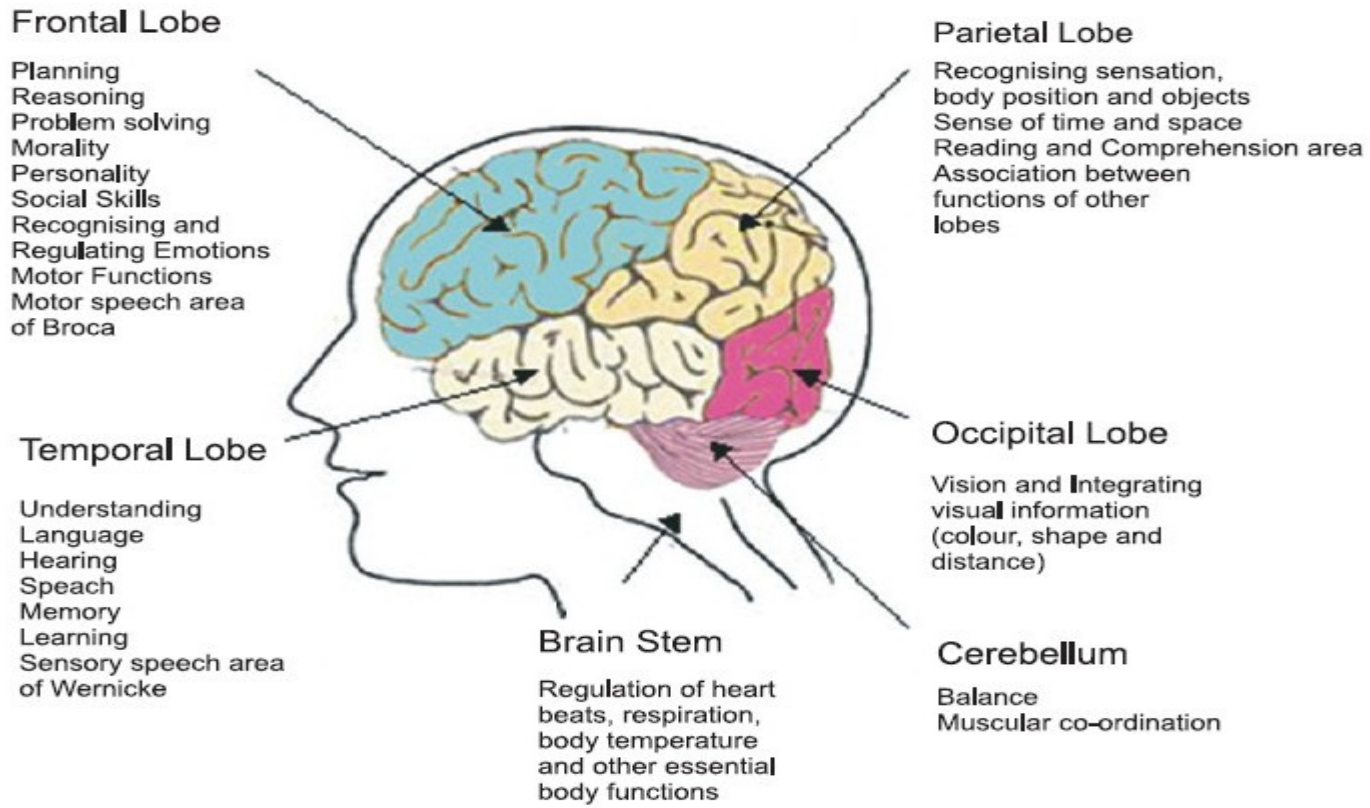
- Text Summarization



Source: Automatic Text Summarization, Cognitive Science and Knowledge Management Series

Vision + Language

- Science Perspective
  - Vision is how we observe and understand the world
  - Language is how we communicate
- A move towards Artificial General Intelligence (AGI)



Source: Barrow Neurological Institute

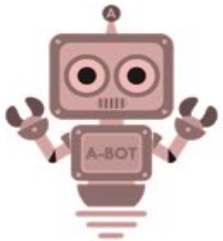
Applications at the intersection of Vision and Language

- To aid “visually impaired” people

Image Credit: https://www.bigrentz.com/blog/ultimate-guide-designing-navigating-spaces-people-vision-impairment

Applications at the intersection of Vision and Language

- To aid “situationally impaired” analysts



Did anyone enter this room last week?

Yes, 127 instances logged on camera

Show me images of anyone carrying a black bag.

...

Slide Credit: Peter Anderson. Connecting Language and Vision to Actions. https://lvatutorial.github.io/

Applications at the intersection of Vision and Language

- Personal Assistants

And what's next?

Add the chopped zucchini to the pan...

Hey, can you order more zucchini?

Done.

Slide Credit: Peter Anderson. Connecting Language and Vision to Actions. https://lvatutorial.github.io/

Applications at the intersection of Vision and Language

- Natural Language Instructions for Robots

Is there smoke in any room around you?

Yes, in one room

Go there and look for people

...

Applications at the intersection of Vision and Language

- Generating and summarizing radiology reports from medical images

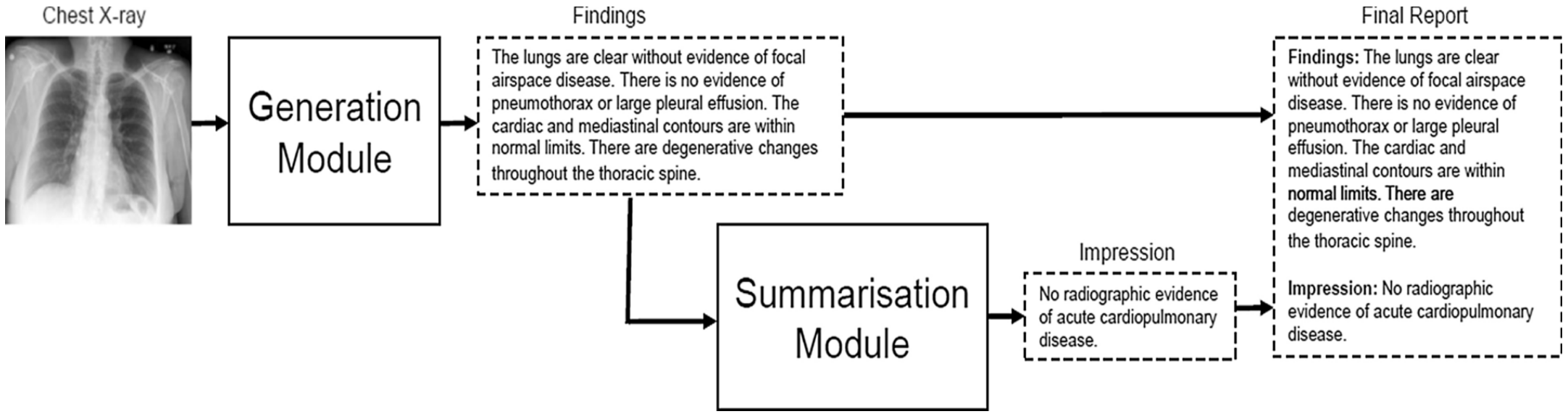
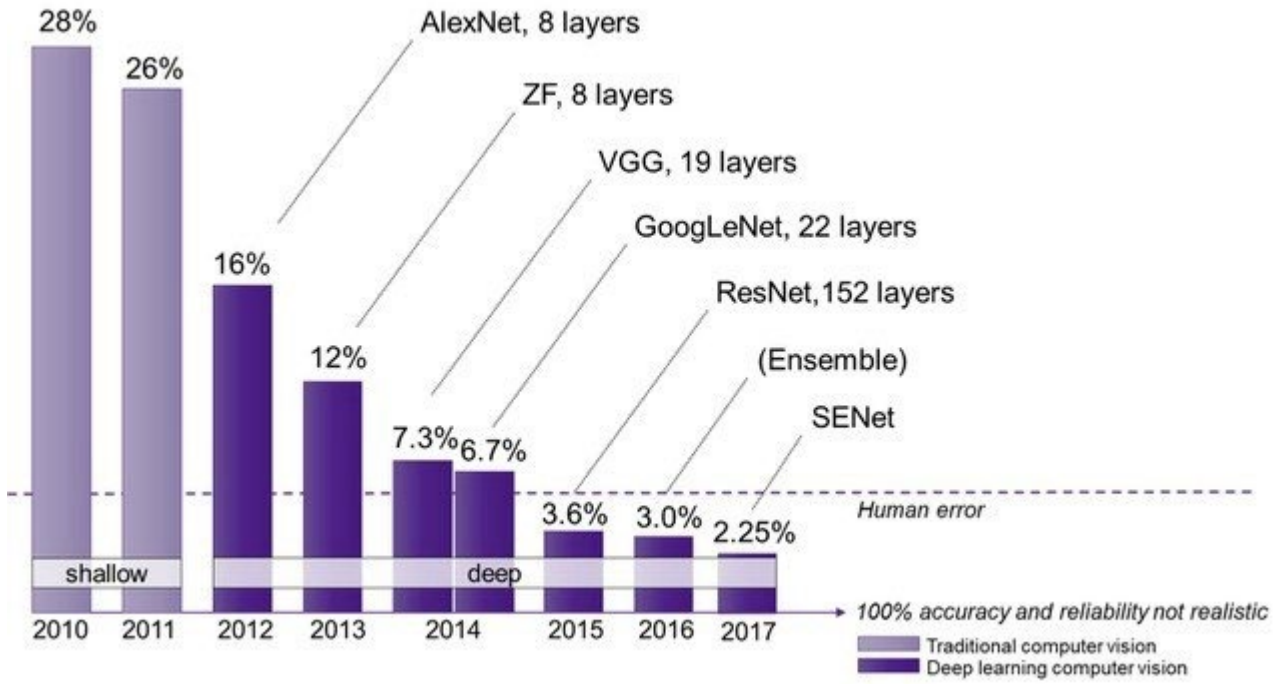


Image Credit: Singh et al., (2021). Show, tell and summarise: learning to generate and summarise radiology findings from medical images

Building Blocks: Convolutional Neural Networks (CNNs)

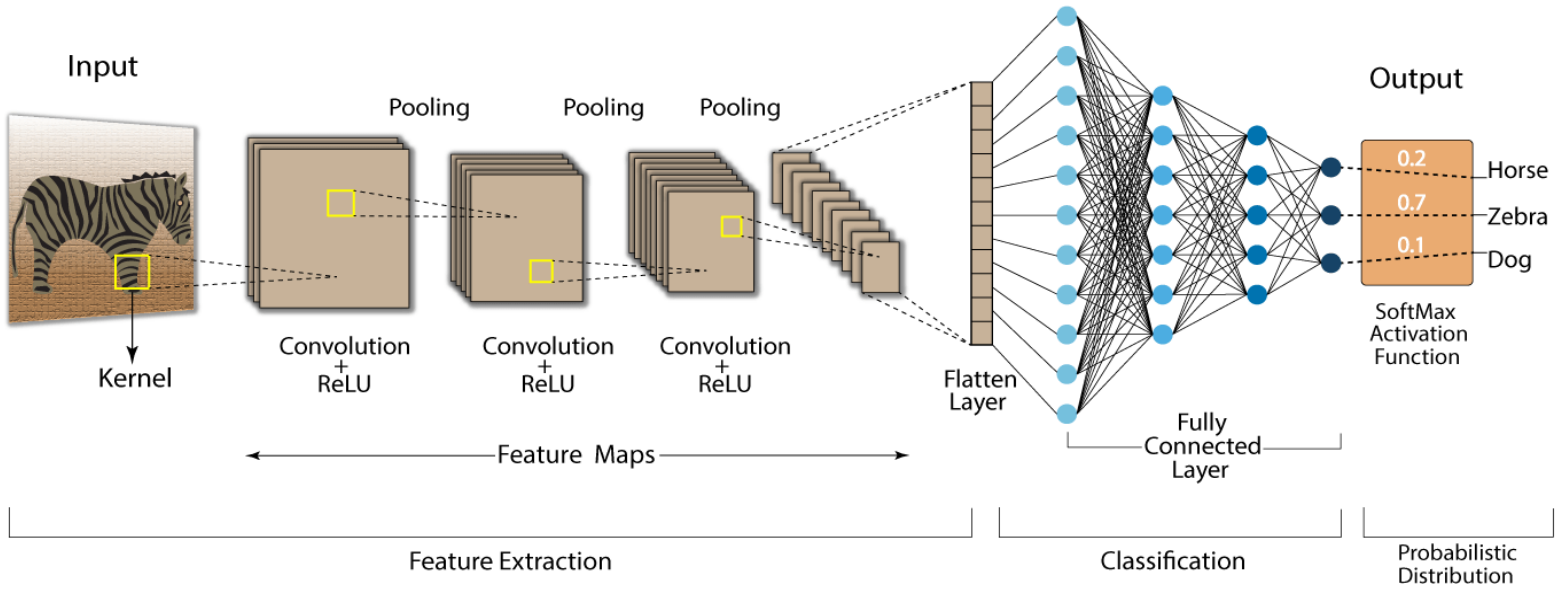
- A class of deep neural networks suitable for processing 2D/3D data. For e.g., Images and Videos
- CNNs can capture high-level representation of images/videos which can be used for end-tasks such as classification, object detection, segmentation, etc.
- A range of CNNs improving over the years



Source: Convolutional Neural Networks. https://medium.com/@rajat.k.91/convolutional-neural-networks-why-what-and-how-f8f6dbebb2f9

CNN Architecture

- A typical CNN architecture consists of the following layers:
  - Convolution layer
  - ReLU layer (non-linearity)
  - Pooling layer
  - Flattening
  - Fully-connected layer
  - Output layer

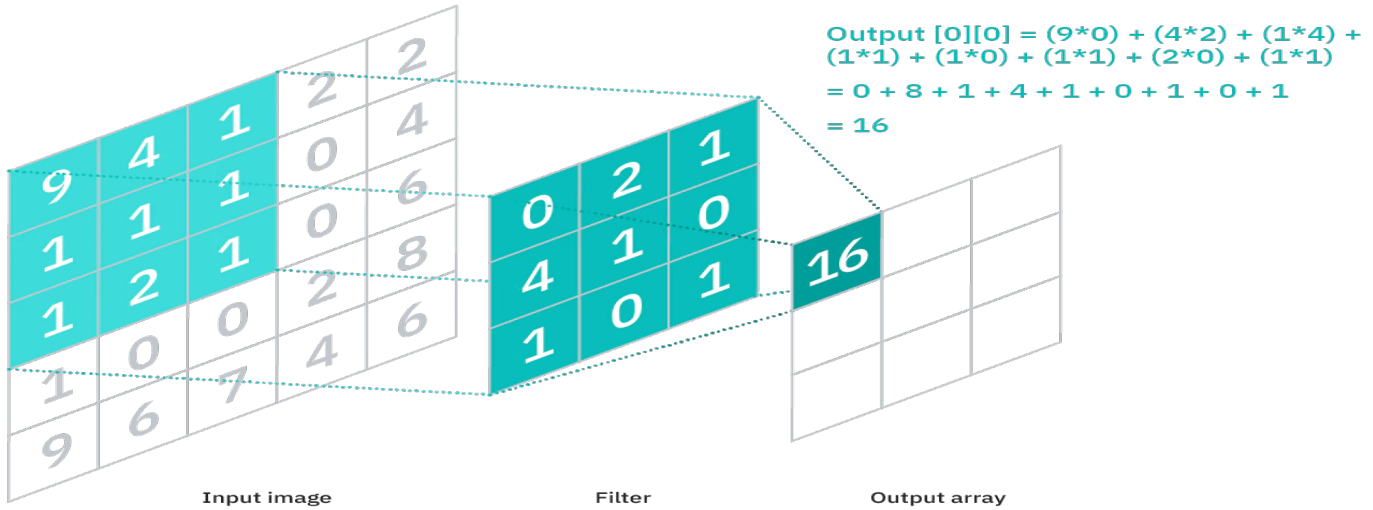


- There can be multiple steps of convolution followed by pooling, before reaching the fully connected layers.

Source: Convolutional Neural Networks. https://medium.com/@rajat.k.91/convolutional-neural-networks-why-what-and-how-f8f6dbebb2f9

Convolution Layer

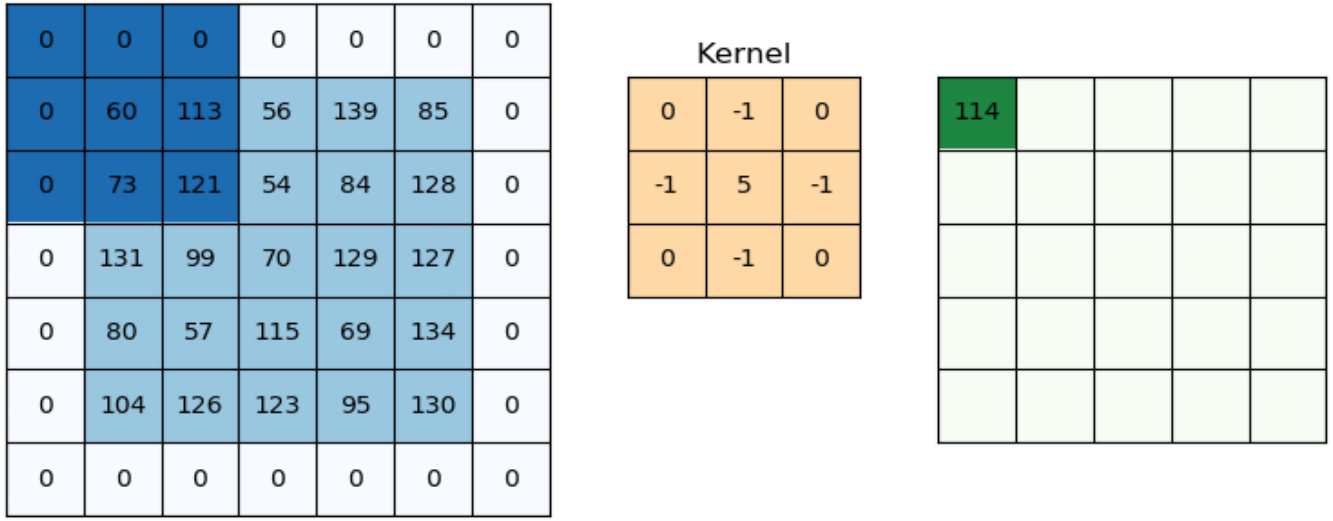
- The convolution layer detect features or visual features in images such as edges, lines, etc.
- The kernel (also, known as filter or feature detector) move across the receptive field of the image and extracts important features
- The filter carries out a convolution operation which is an element-wise product and sum between two matrices
- Given output value in the feature map does not have to connect to each pixel in the input image, it only needs to connect to the receptive filed, where the filter is being applied. This characteristic is described as “local connectivity”



Source: https://www.ibm.com/cloud/learn/convolutional-neural-networks

Convolution in action

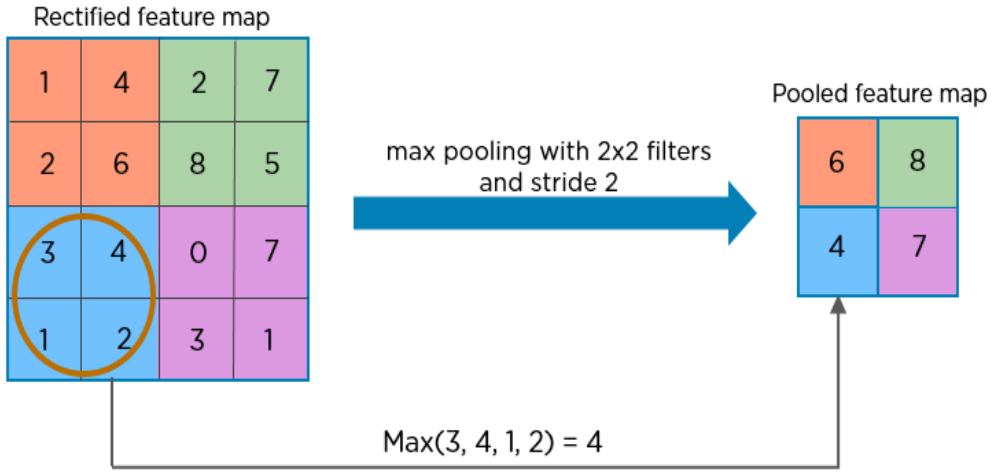
- We need multiple number of filters (feature detectors) to detect different curves/edges or features in the image
- The result of convolving filter over the entire image is an output matrix called feature maps or convolved features that stores the convolutions of the filter over various parts of the image
- N filters produces N feature maps

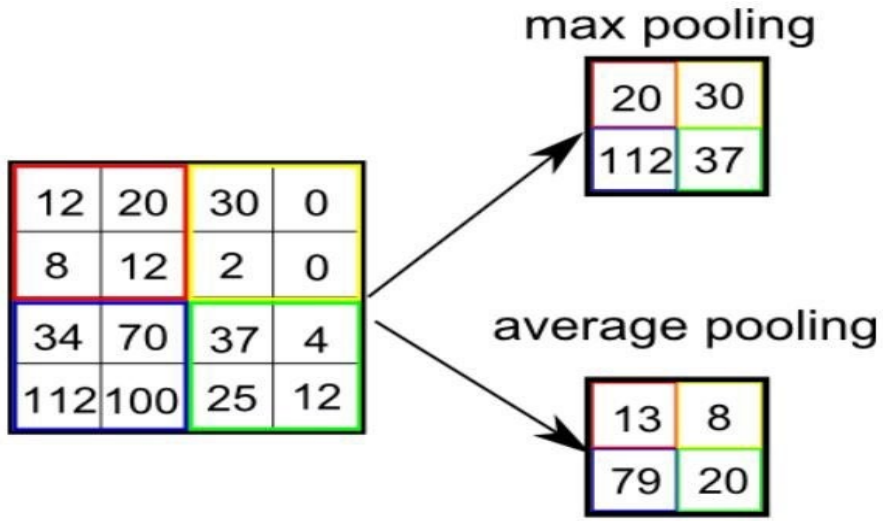


Source: https://www.kdnuggets.com/2020/06/introduction-convolutional-neural-networks.html

Subsampling or Pooling Layer

- Pooling is a down-sampling operation that reduces the dimensionality of the feature map.
- Each ReLU feature map pass through the pooling layer to generate a pooled feature map.
- Two of the important pooling operations are:
  - Max pooling: As the filter moves across the input, it selects the pixel with the maximum value to send to the output array
  - Average pooling: As the filter moves across the input, it calculates the average value within the receptive field to send to the output array.



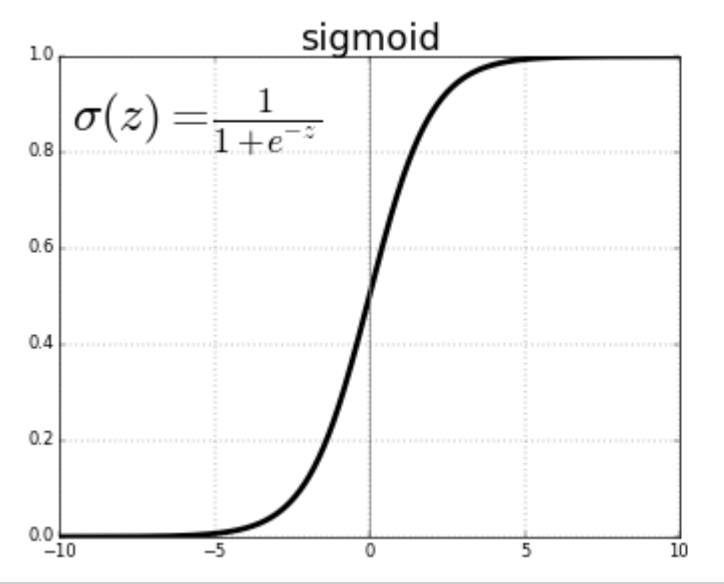


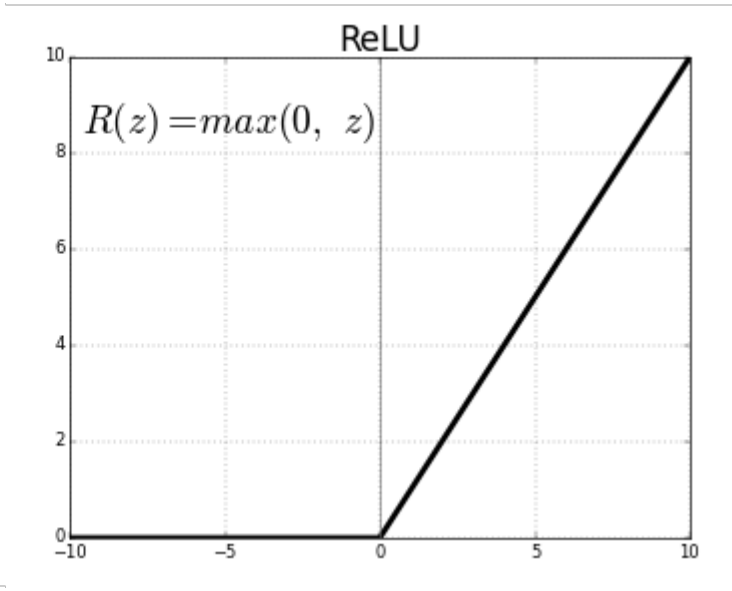
- Although there is information loss due to pooling, it helps to reduce complexity, improve efficiency, and limit risk of overfitting.

Source: https://www.simplilearn.com/tutorials/deep-learning-tutorial/convolutional-neural-network

Non-linearity layers (ReLU)

- Since convolution is a linear operation, non-linearity layers are often placed directly after the convolutional layer to introduce non-linearity to the activation map.
- Main non-linear operators are:
  - Sigmoid
  - Tanh
  - ReLU
- ReLU is more reliable and accelerates the model convergence

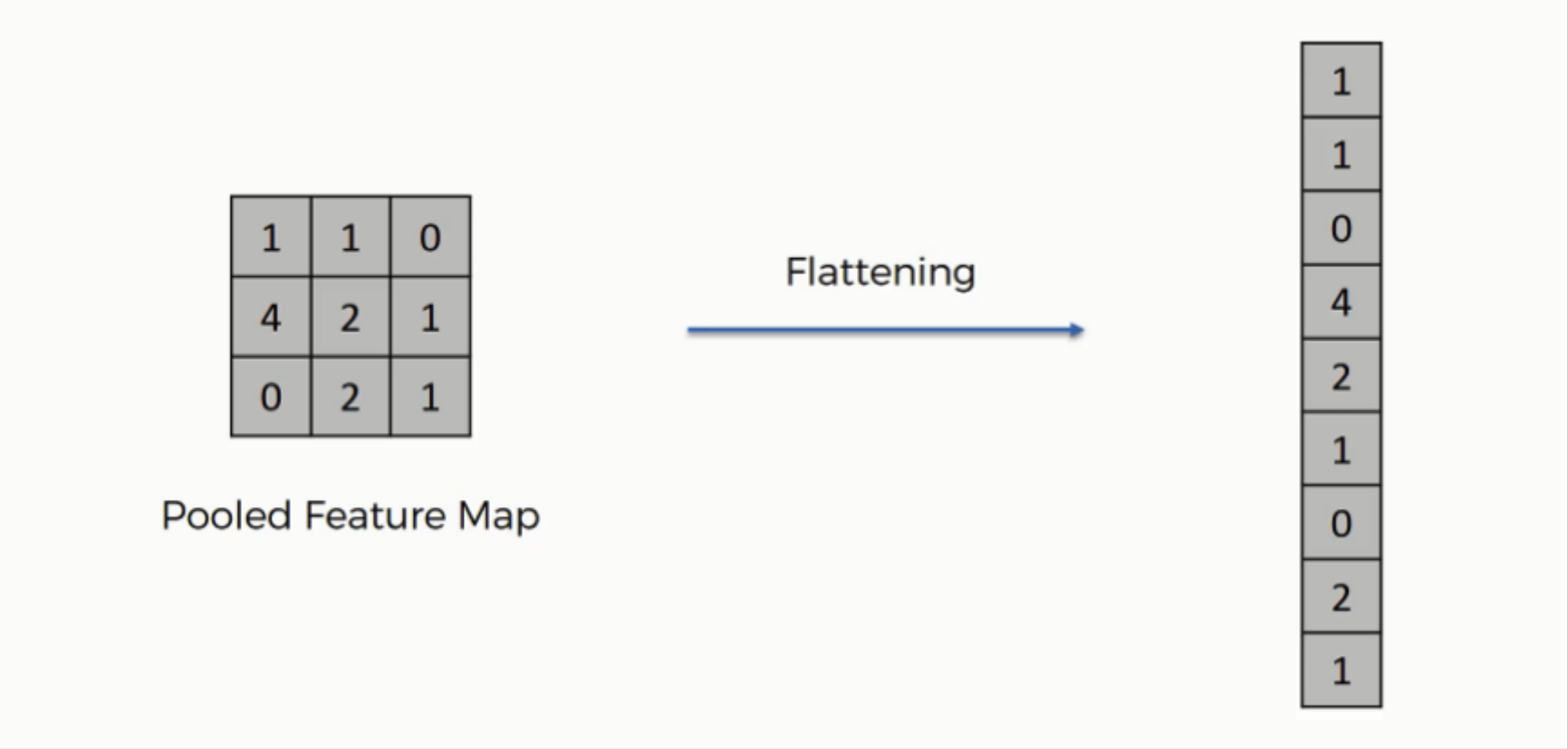




Source: https://towardsdatascience.com/activation-functions-neural-networks-1cbd9f8d91d6

Flattening

- After multiple convolution layers and pooling operations, the 3D representation of the image is converted into a feature vector that is passed into a multi-layer perception (MLP)



Source: https://www.kdnuggets.com/2020/06/introduction-convolutional-neural-networks.html

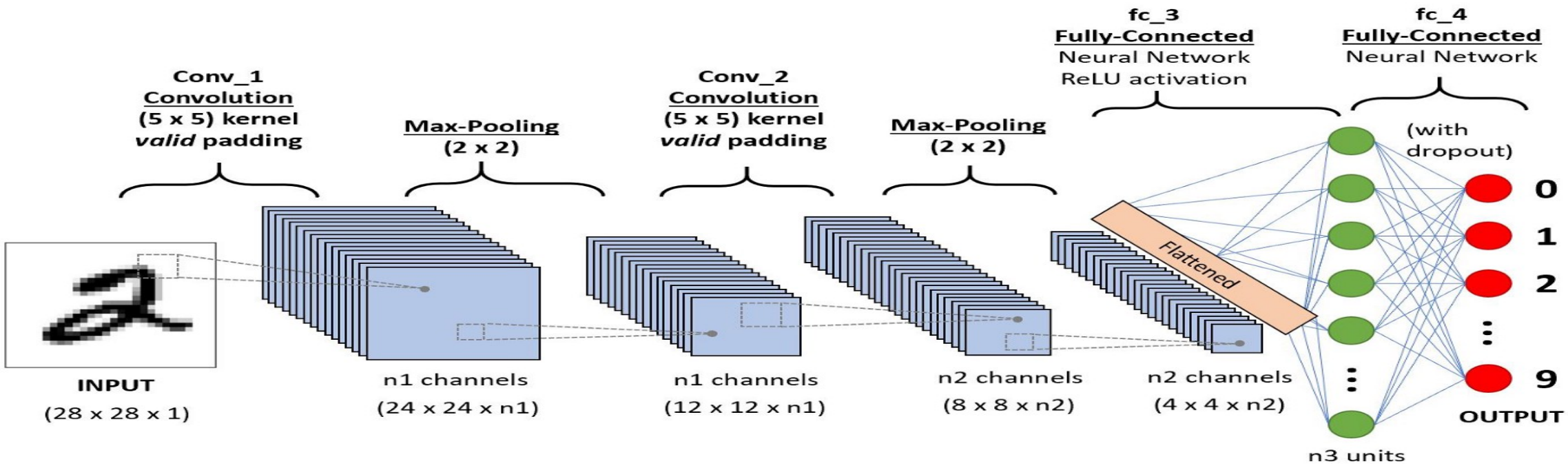
Fully-Connected Layer(s)

- The FC layer comprises the weights and biases together with the neurons and is used to connect the neurons between two separate layers.
- In FC layer, each node in the output layer connects directly to a node in the previous layer.
- The flattened feature map is passed through the FC layer(s)

Source: Convolutional Neural Networks. https://medium.com/@rajat.k.91/convolutional-neural-networks-why-what-and-how-f8f6dbebb2f9

Output Layer

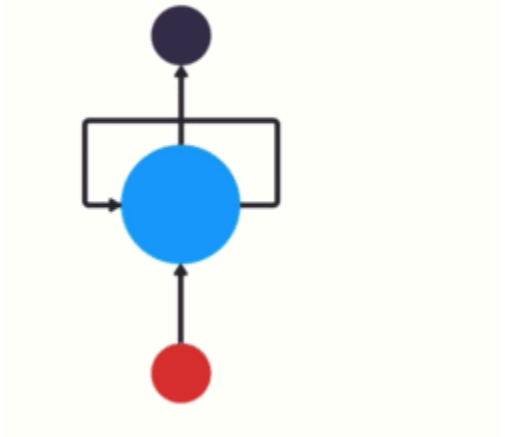
- The output layer produces the probability of each class given the input image
- This is the last layer containing the same number of neurons as the number of classes in the dataset
- The output of this layer passes through the Softmax activation function to normalize the output to have probability sum to one



Source: Convolutional Neural Networks. https://medium.com/@rajat.k.91/convolutional-neural-networks-why-what-and-how-f8f6dbebb2f9

Building Blocks: Recurrent Neural Networks (RNNs)

- A class of neural networks suitable for processing temporal or sequential data
- The basic unit of RNN is called “cell”, and each cell consists of layers and a series of cells that enables the sequential processing of recurrent neural network models
- RNNs have a looping mechanism that acts as a highway to allow information to flow from one step to the next. This information is the hidden state, which is a representation of previous inputs.



Credit: Michael Phi. Illustrated guide to RNNs. https://towardsdatascience.com/illustrated-guide-to-recurrent-neural-networks-79e5eb8049c9

Long-range Dependency problem

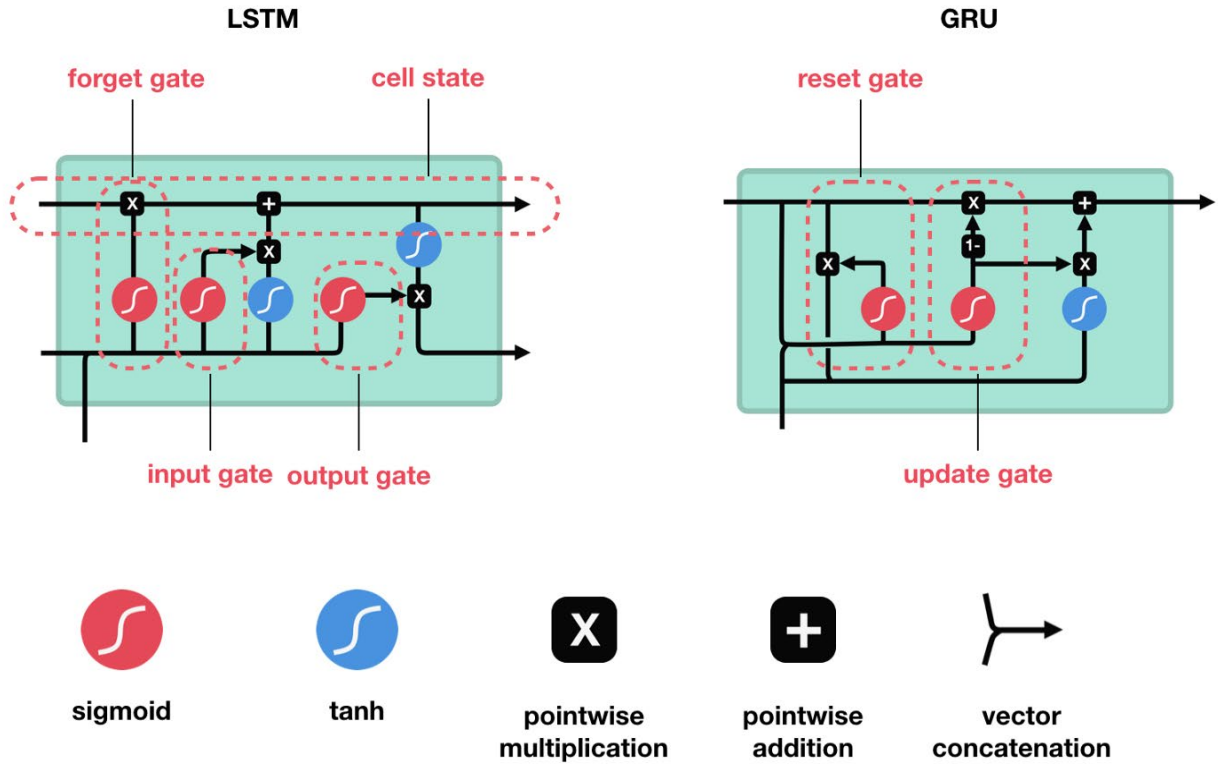
- Vanilla RNNs suffers from vanishing gradient problem
  - As the RNNs processes more steps, it has troubles retaining information from previous steps.
  - Due to back-propagation, the earlier layers fail to do any learning as the internal weights are barely being adjusted due to extremely small gradients.
  - Does not learn the long-range dependencies across time steps

"Once upon a time, there was a king who ruled a great and glorious nation. Favourite amongst his subjects was the court painter of whom he was very proud. Everybody agreed this wizzened old man painted the greatest pictures in the whole kingdom and the king would spend hours each day gazing at them in wonder. However, one day a dirty and disheveled stranger presented himself at the court claiming that in fact he was the greatest painter in the land. The indignant king decreed a competition would be held between the two artists, confident it would teach the vagabond an embarrassing lesson. Within a month they were both to produce a masterpiece that would out do the other. After thirty days of working feverishly day and night, both artists were ready. They placed their paintings, each hidden by a cloth, on easels in the great hall of the castle. As a large crowd gathered, the king ordered the cloth be pulled…"

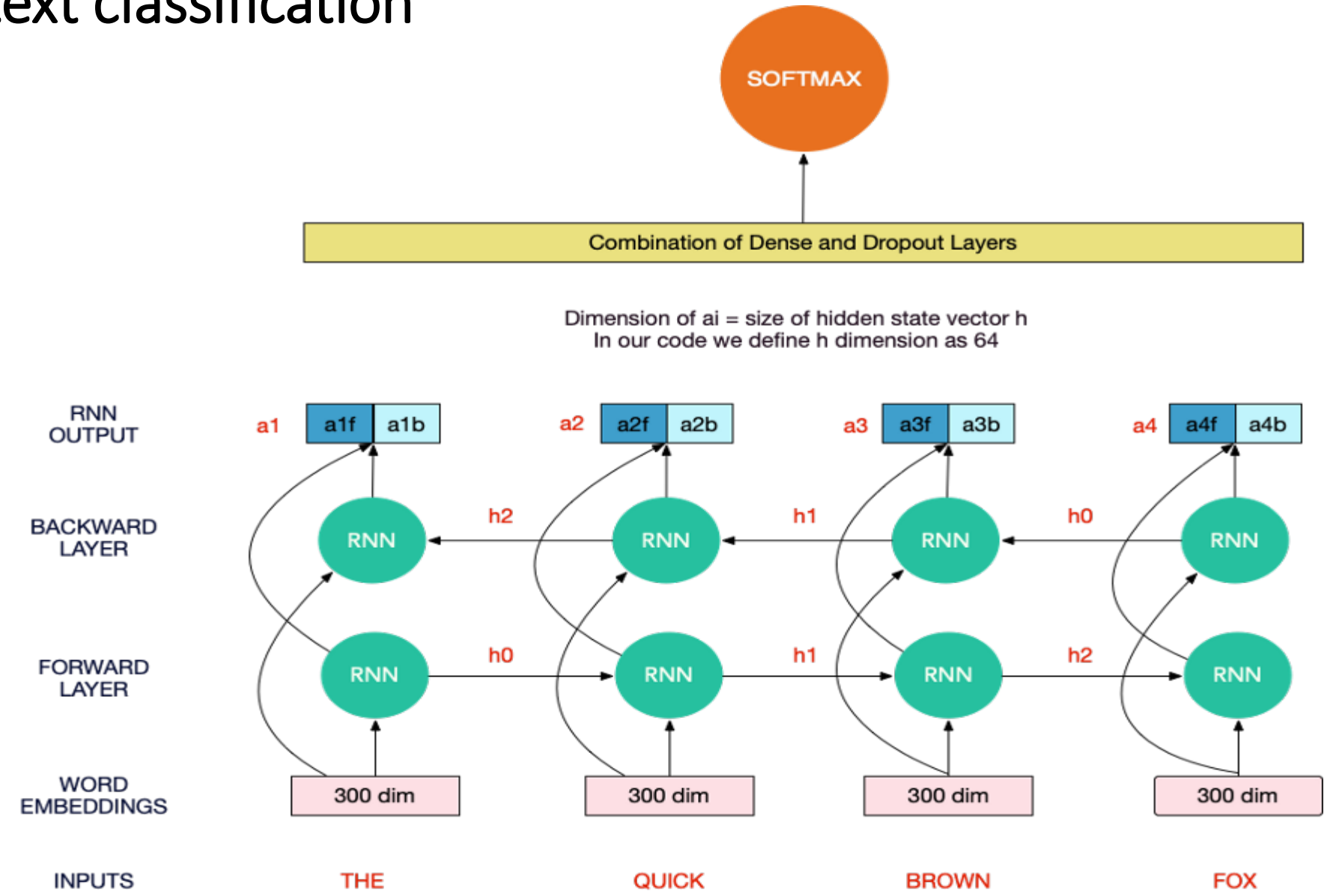
Credit: https://www.goodreads.com/quotes/51722-once-upon-a-time-there-was-a-king-who-ruled

LSTMs/GRUs

- LSTMs and GRUs are two special RNNs, capable of learning long-term dependencies using mechanisms called **gates**.
- These gates are different tensor operations that can learn what information to add or remove to the hidden state.



End-to-End text classification



Seq2Seq model

- Model has two parts: Encoder and Decoder (Encoder-Decoder Framework)

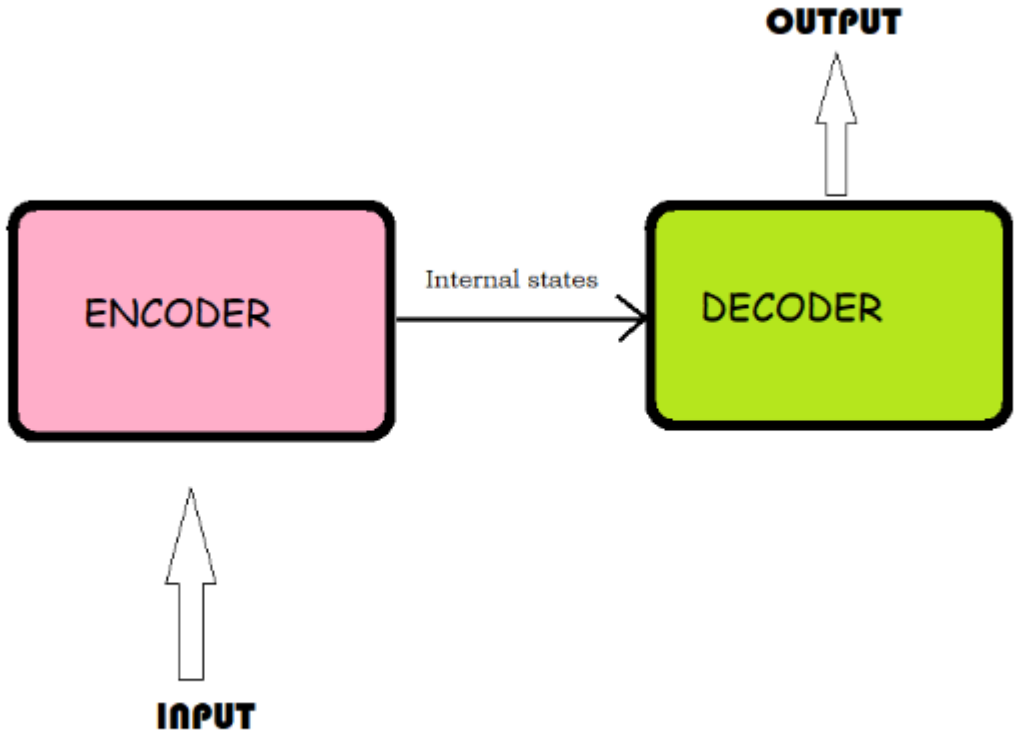
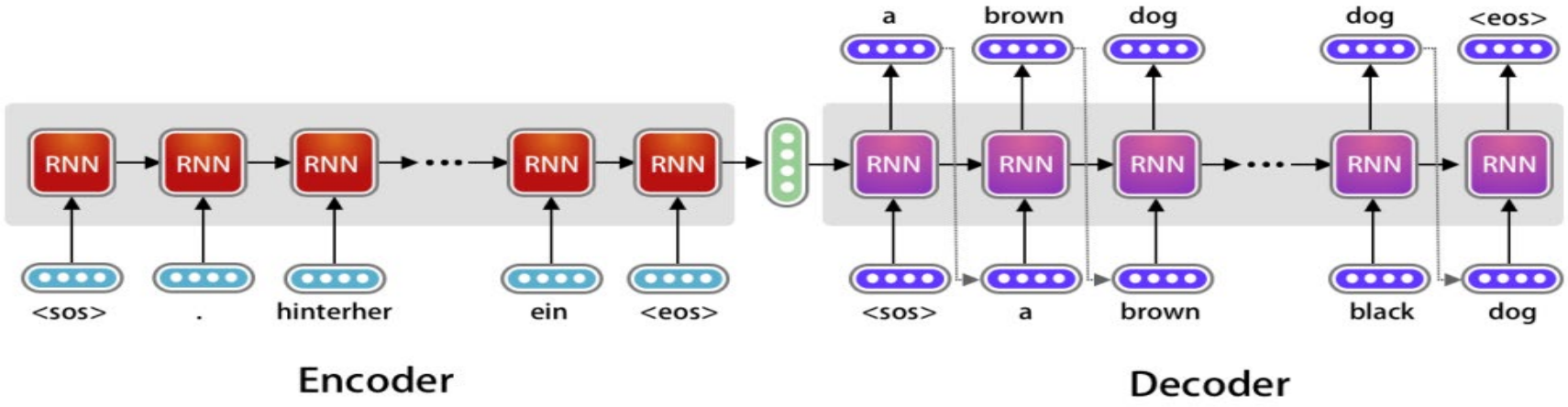


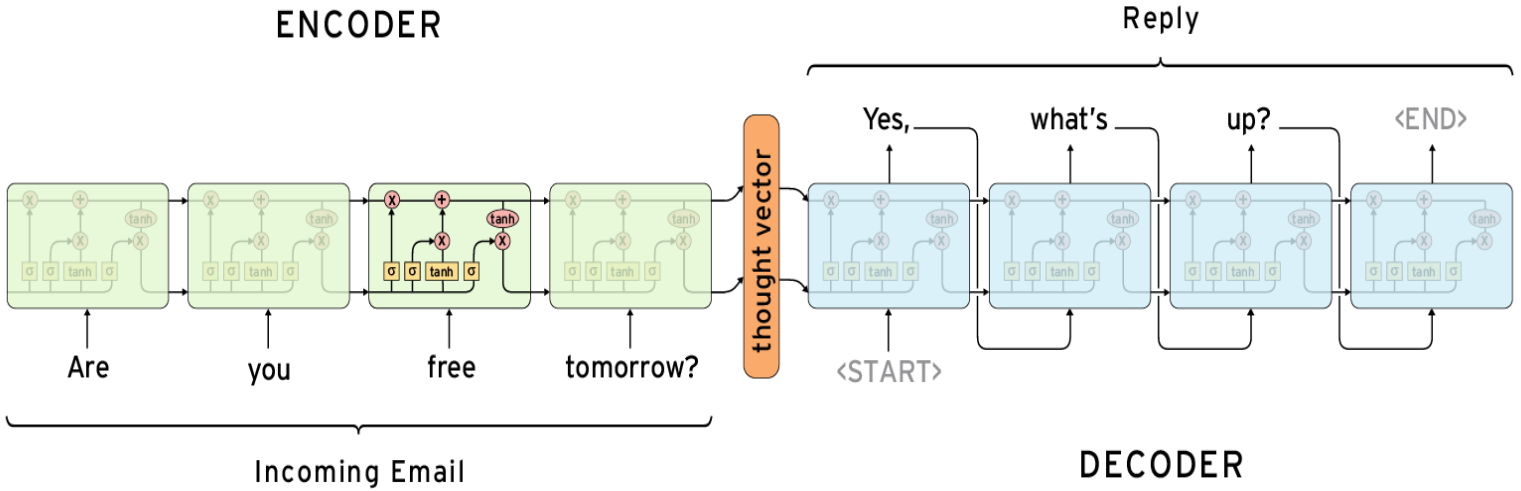
Image Credit: Machine Translation using Recurrent Neural Network and PyTorch. http://www.adeveloperdiary.com/data-science/deep-learning/nlp/machine-translation-recurrent-neural-network-pytorch/

Seq2Seq used for various NLP applications

- Machine Translation



- Automatic Email Reply



Seq2Seq used for various NLP applications

- Google's Multilingual Neural Machine Translation

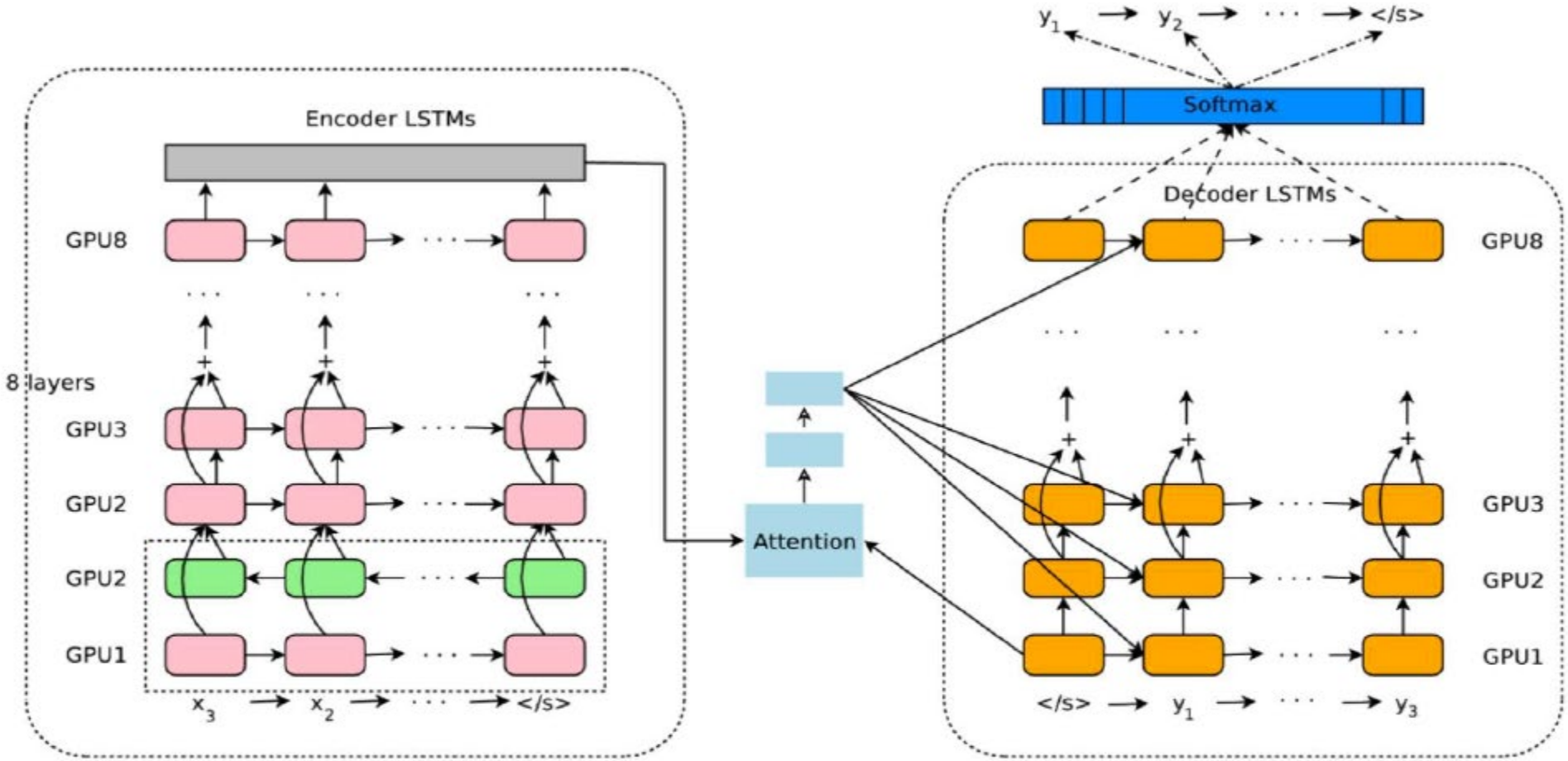
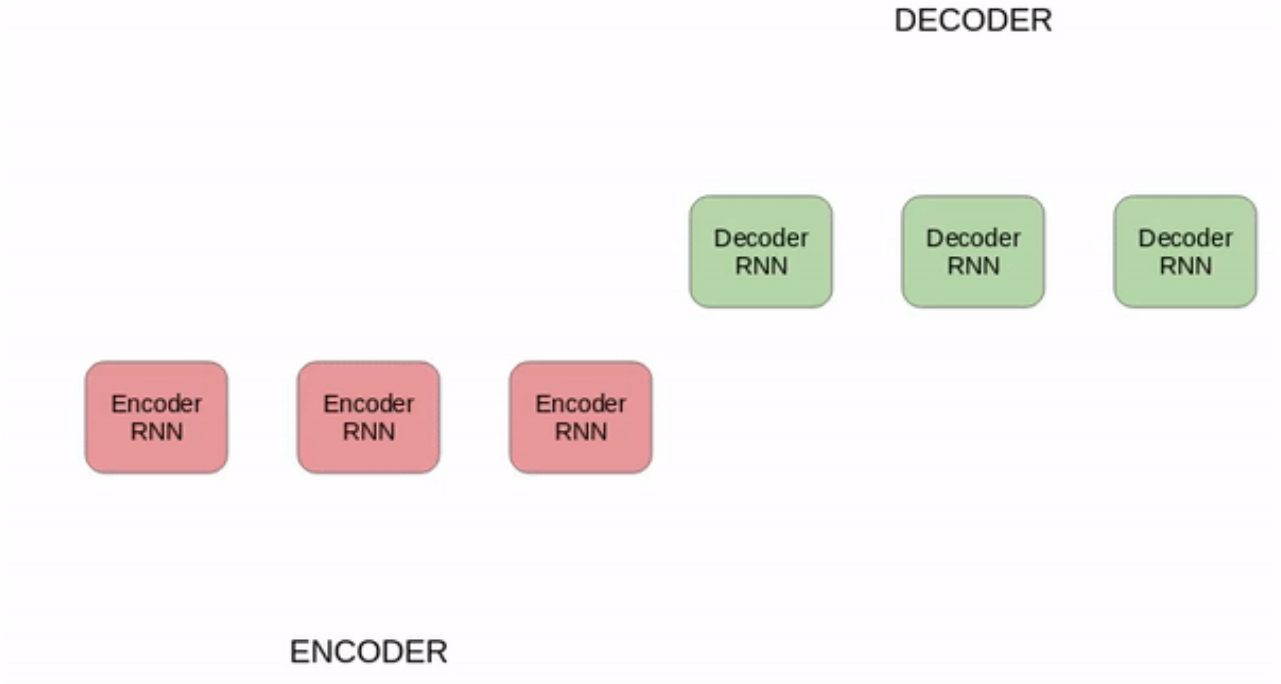


Image Credit: https://arxiv.org/abs/1611.04558?context=cs.AI

Issues with RNNs for seq2seq tasks

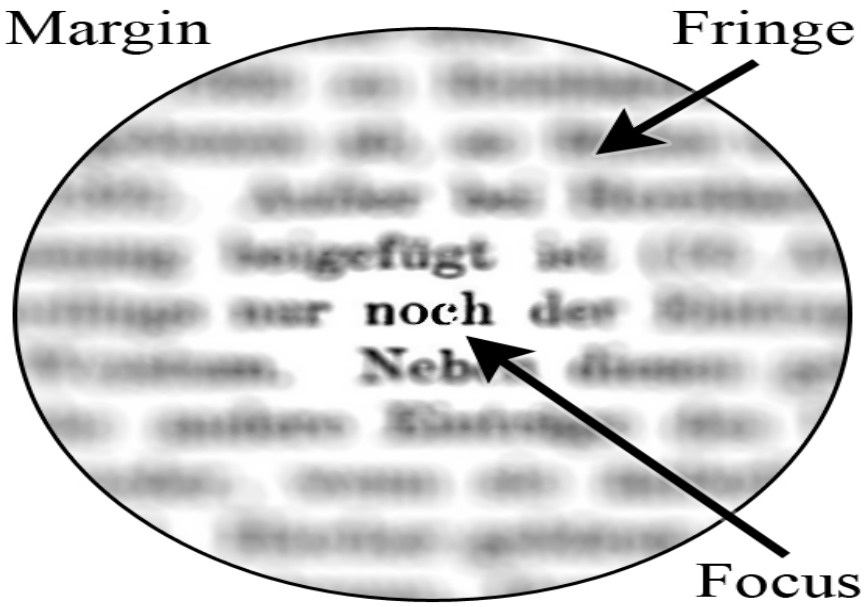
- Despite being very successful for various NLP tasks, there were challenges:
  - dealing with long-range dependencies
  - the sequential nature of the architecture prevents parallelization
- Attention mechanism helped to overcome first issue to certain extent



Credit: Encoder-Decoder Architecture for Machine Translation. https://www.analyticsvidhya.com/blog/2019/06/understanding-transformers-nlp-state-of-the-art-models/

Attention Mechanism

- A set of mechanisms that limit some processing to a subset of incoming stimuli (reducing computational demands)
- Attention in neural networks
  - A mechanism that learns to focus on a subset of the input that is relevant to the task.



task context representation

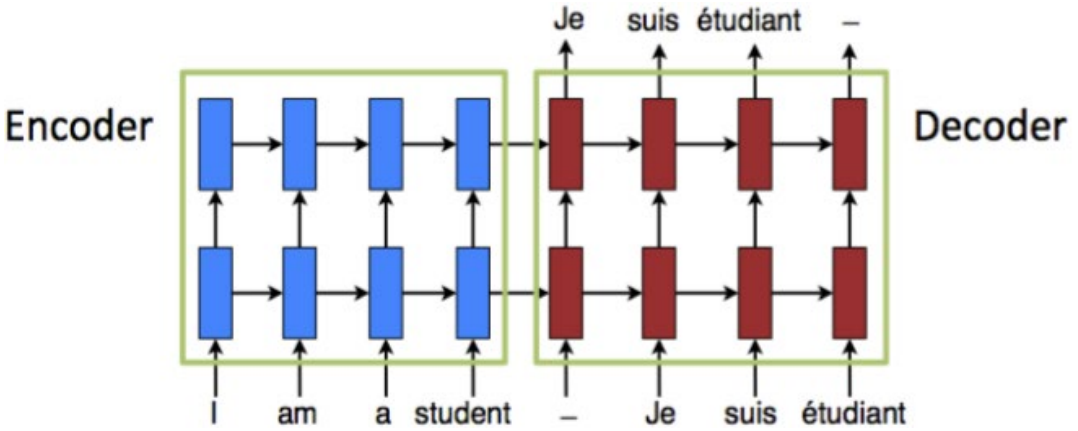
attended feature $\rightarrow \hat{v} = f(h, V)$

learned attention function (neural net)

set of attention candidates

Neural Machine Translation by jointly Learning to Align and Translate

- NMT attempts to build and train a single, large neural network that reads a sentence and outputs a correct translation.
- The NMT system is a seq2seq model (Encoder-Decoder framework)
- Issue: The encoder-decoder framework compresses all the necessary information of a source sentence into a fixed-length vector.



- Cho et al. (2014) showed that the performance of a basic encoder-decoder deteriorates as the length of an input sentence increases.
- Bahdanau et al. (2015) proposed an extension to NMT which learns to align and translate jointly.
- The basic idea of "attention" is that **at each time the model generates a word in a translation, it searches for a set of positions in a source sentence where the most relevant information is concentrated**
- **The model predicts a target word based on the context vectors associated with these source positions and all the previous generated target words**

Credit: Bahdanau et al. (2015). Neural Machine Translation by jointly learning to Align and Translate. ICLR 2015.

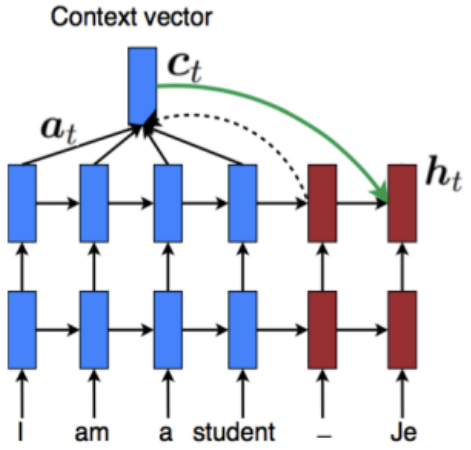
Neural Machine Translation by jointly Learning to Align and Translate

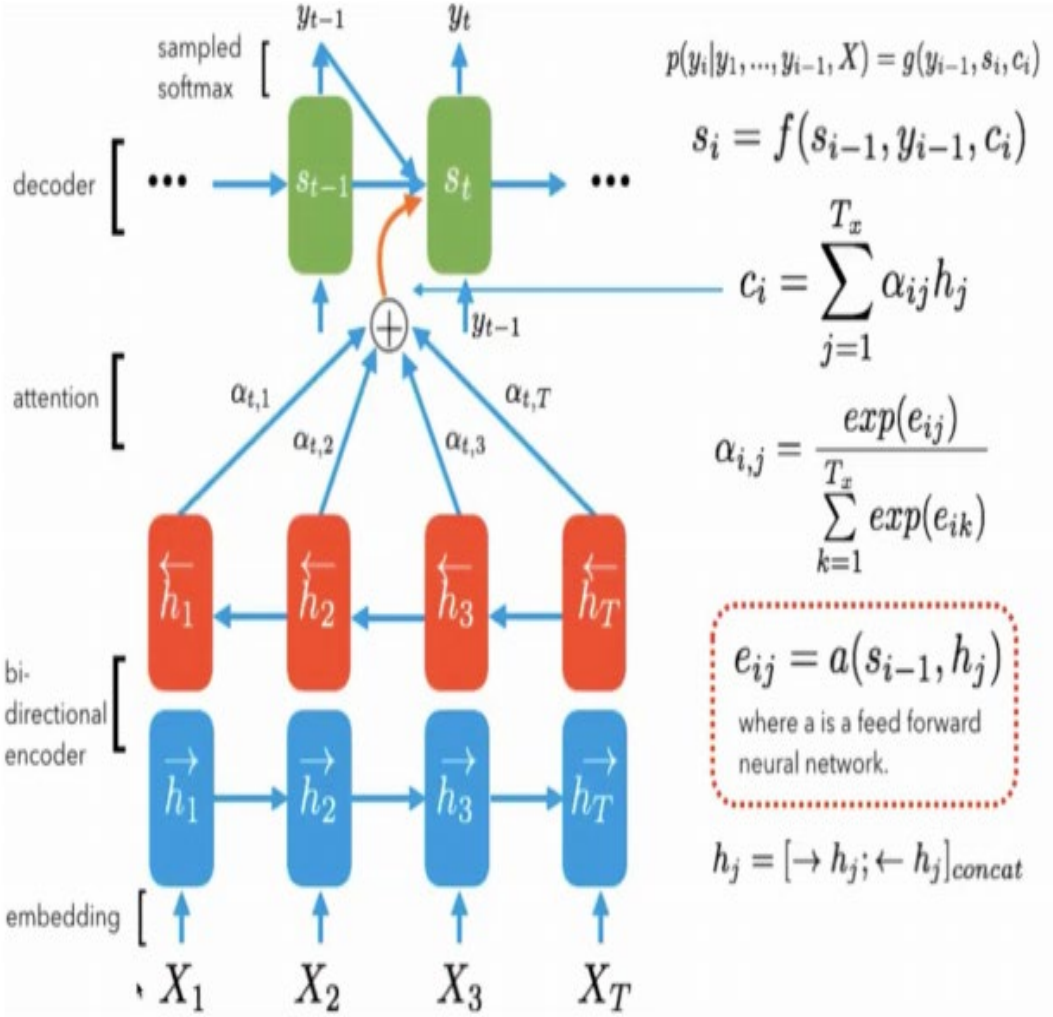
- Issue: The encoder-decoder framework compresses all the necessary information of a source sentence into a fixed-length vector.
- Solution: Enable the network to pay attention to specific areas of the input by adding new (weighted) connections

$$c_i = \sum_{j=1}^{T_x} \alpha_{ij} h_j$$

$$\alpha_{ij} = \frac{\exp(e_{ij})}{\sum_{k=1}^{T_x} \exp(e_{ik})},$$

$$e_{ij} = a(s_{i-1}, h_j)$$

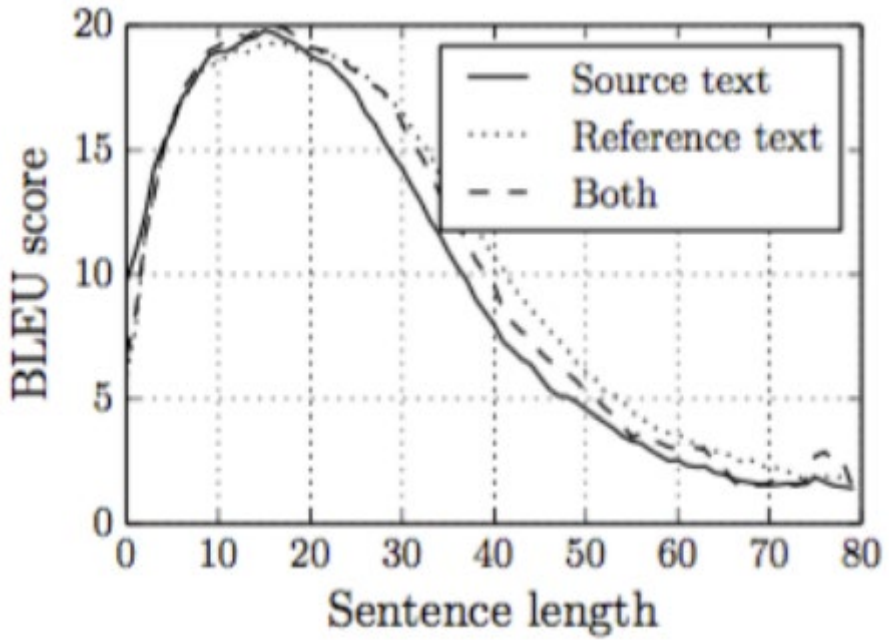




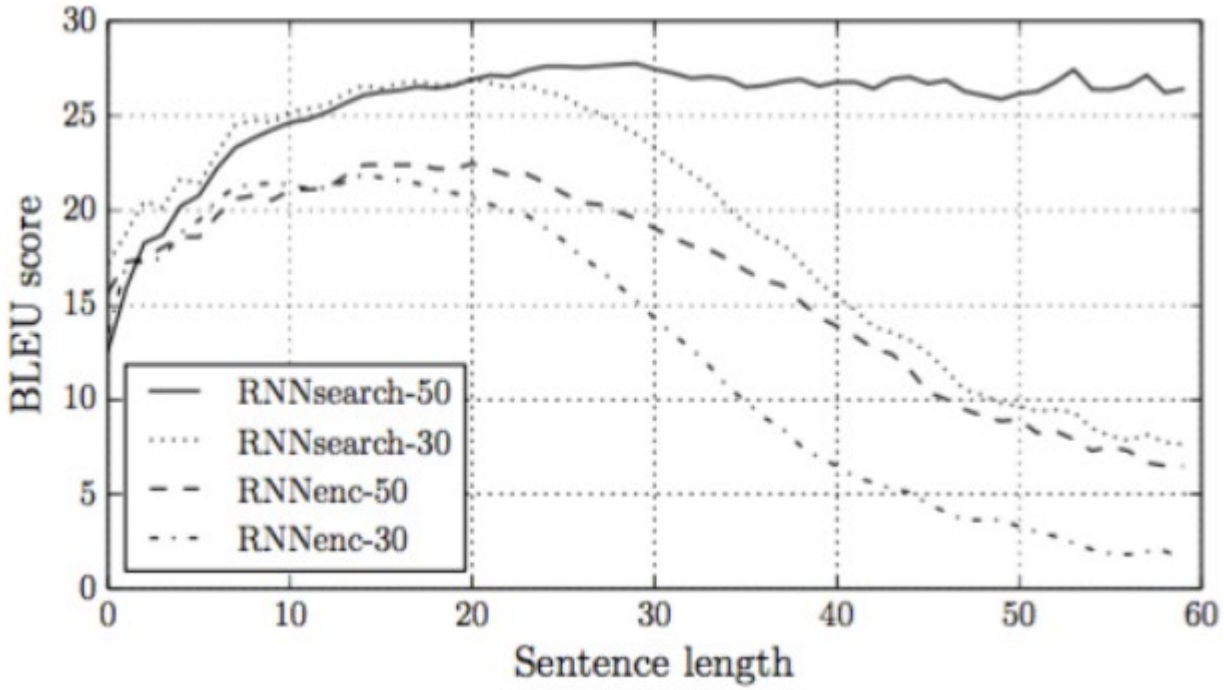
Credit: Bahdanau et al. (2015). Neural Machine Translation by jointly learning to Align and Translate. ICLR 2015.

NMT by jointly Learning to Align and Translate

Before Attention: Long sentences are very hard as they are compressed to a fixed length vector



After Attention: The attention mechanism helps to overcome the issue



Credit: Bahdanau et al. (2015). Neural Machine Translation by jointly learning to Align and Translate. ICLR 2015.

Image Captioning

- Developing models to generate textual description of an image

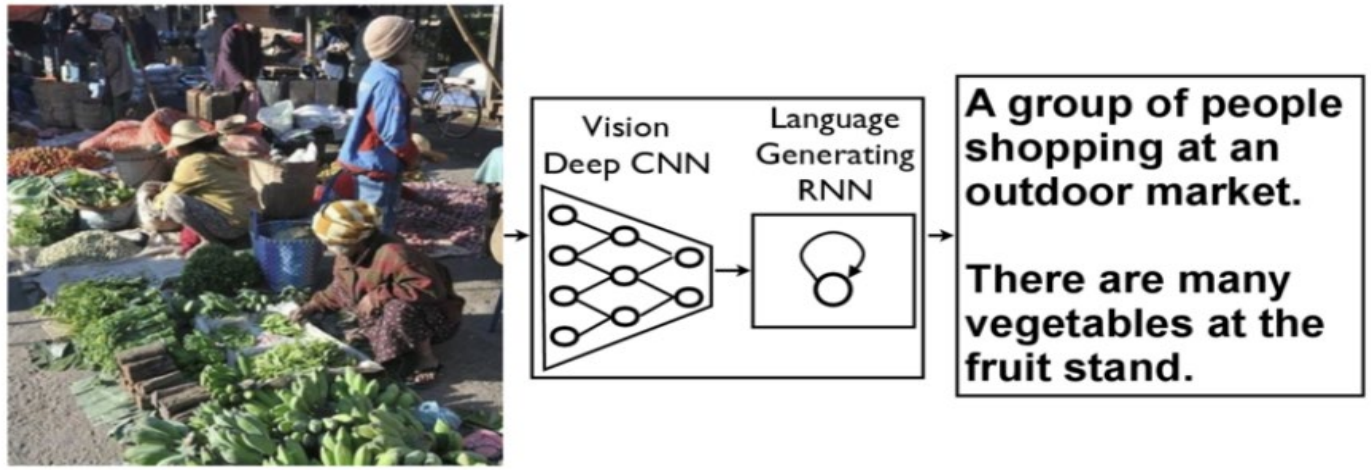
"man in black shirt is playing guitar."

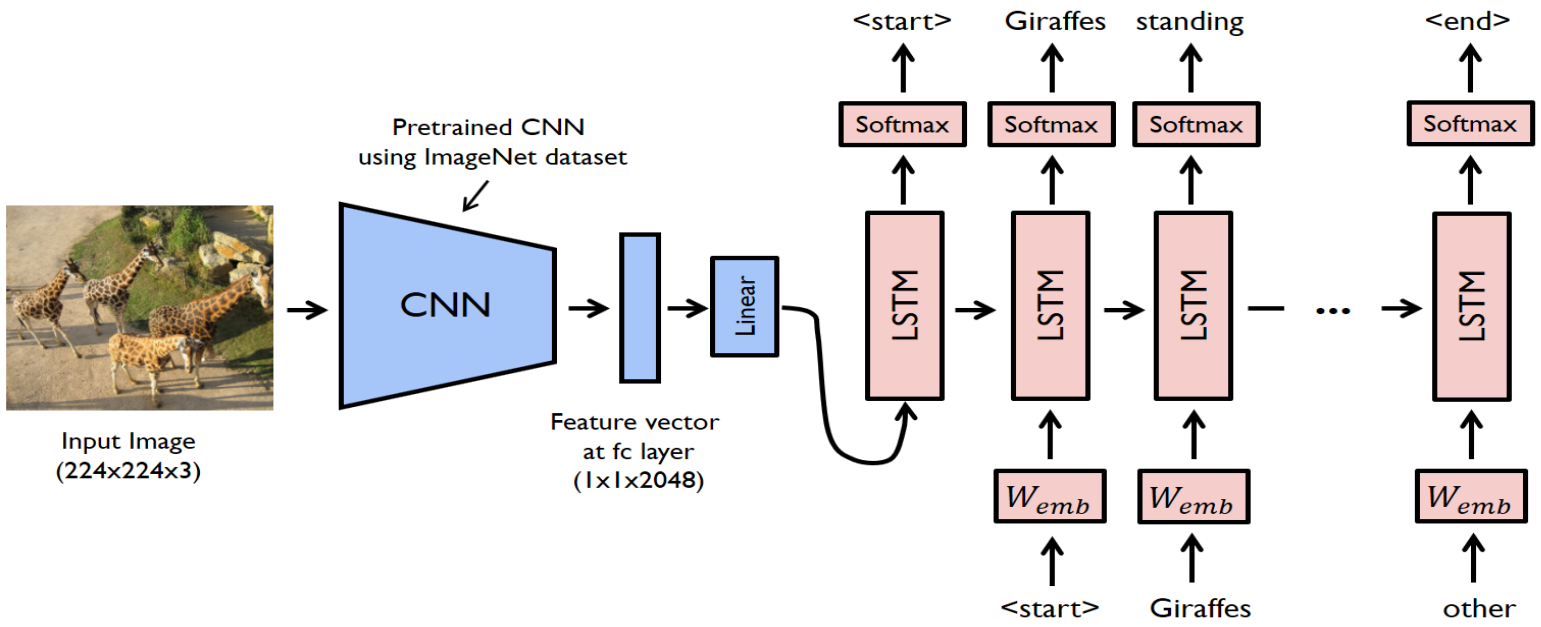
"construction worker in orange safety vest is working on road."

"two young girls are playing with lego toy."

Image Credit: Machine Translation using Recurrent Neural Network and PyTorch. http://www.adeveloperdiary.com/data-science/deep-learning/nlp/machine-translation-recurrent-neural-network-pytorch/

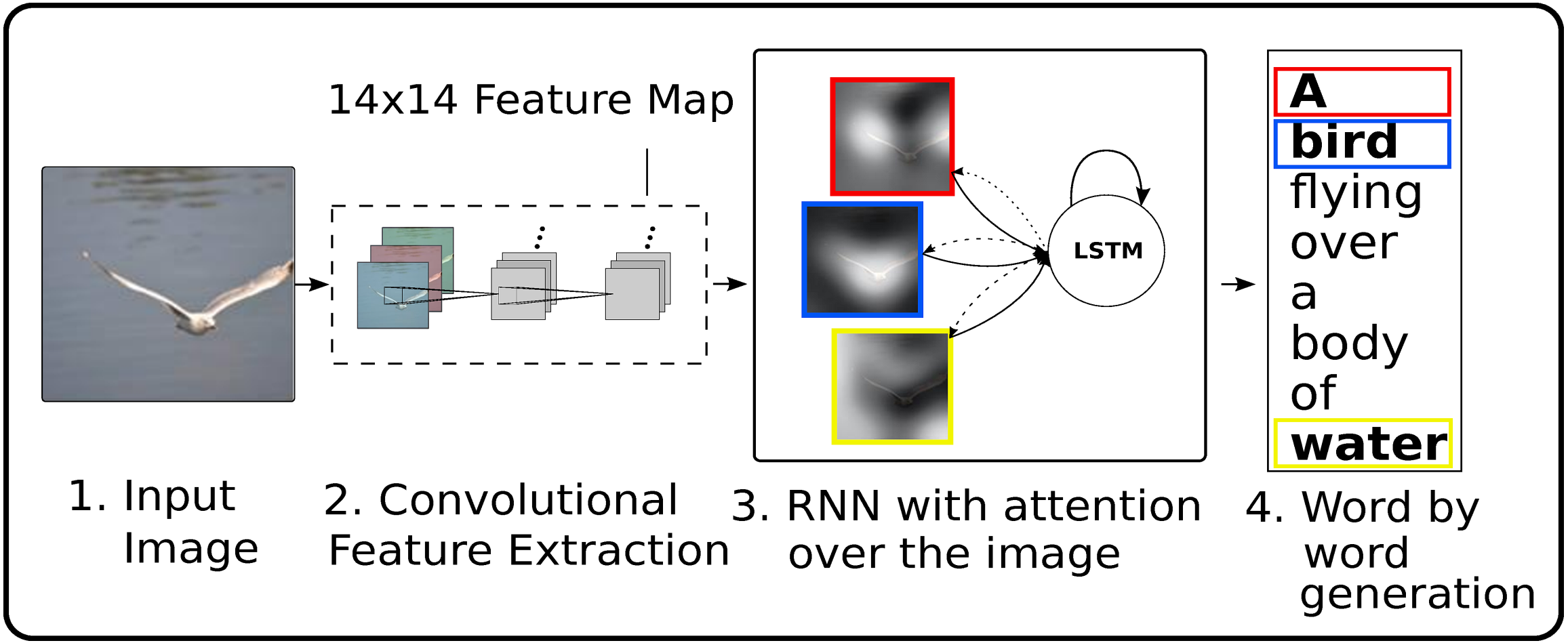
Show and Tell (Vinyals et al., 2015)



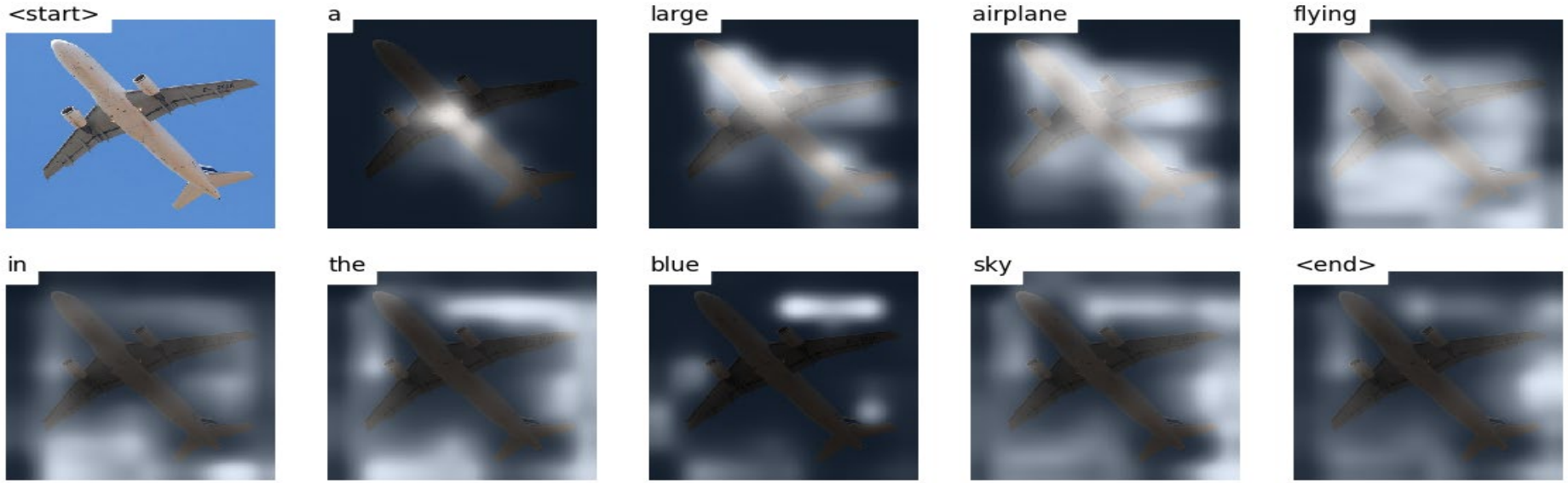


Show, Attend and Tell (Xu et al., 2015)

- "Rather than compressing an entire image into static representation, attention allows for **salient features** to dynamically come to forefront as needed"



Show, Attend and Tell (Xu et al., 2015)



Source: Xu et al., (2015). Show, Attend and Tell: Neural Image Caption Generation with Visual Attention

Image Captioning with Semantic Attention (You et al., 2016)

- Learns to selectively attend to semantic concept proposals and fuse them into hidden states and outputs of RNNs.

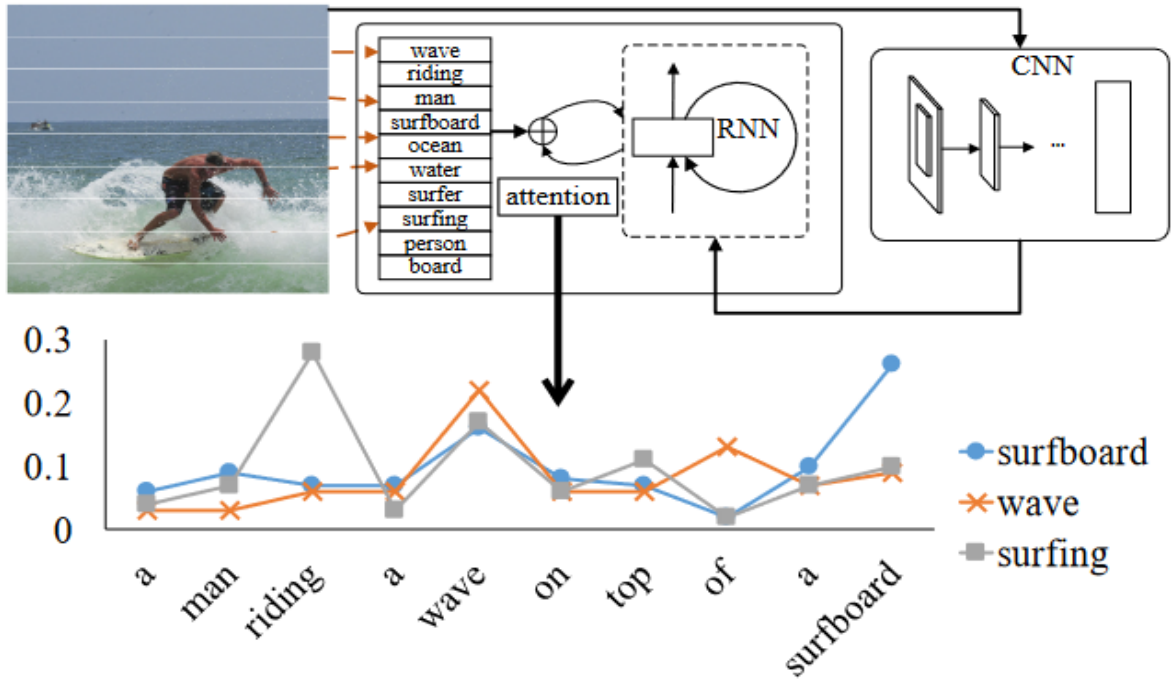


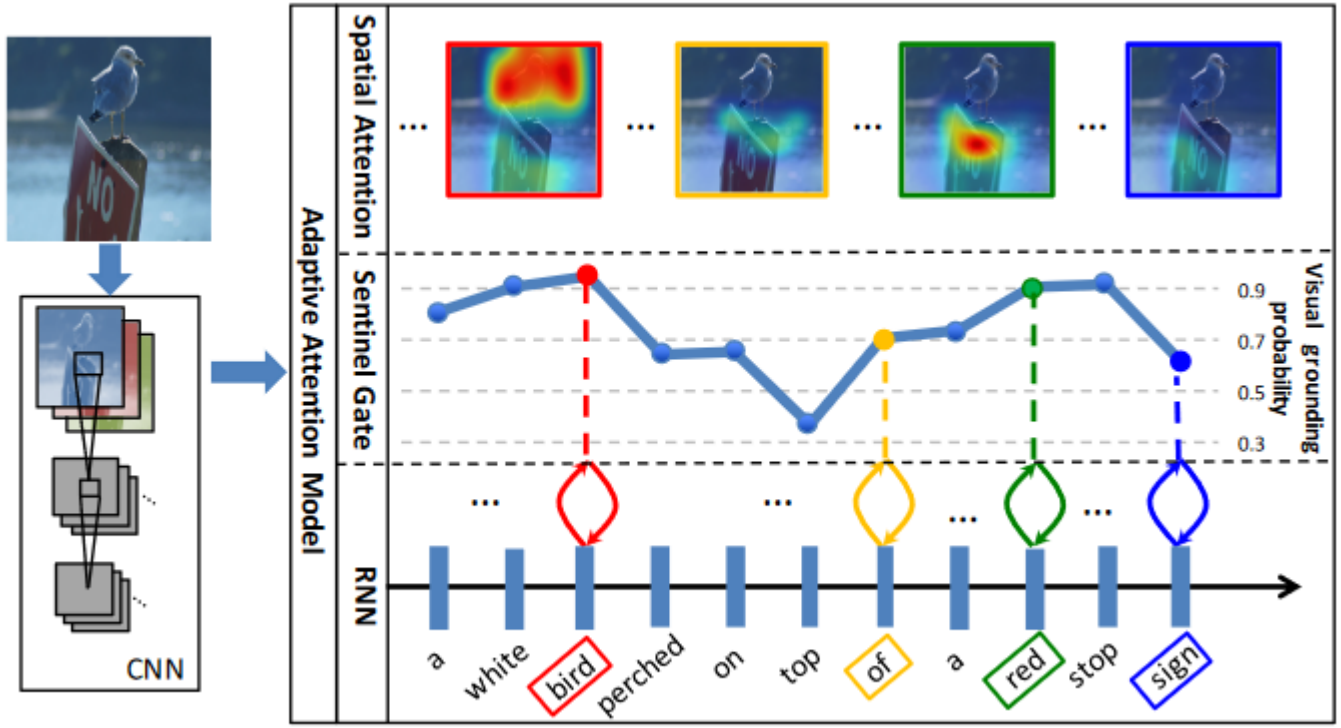
Image Captioning with Semantic Attention (You et al., 2016)

- Learns to selectively attend to semantic concept proposals and fuse them into hidden states and outputs of RNNs.

Source: You et al., (2016). Image Captioning with Semantic Attention

Knowing When to Look (Lu et al., 2017)

- Words such as “a”, “of”, “it” may be seen as not worth attending
- Words such as “woman”, “dog”, “traffic light” need attending to the image
- Automatically determines when to look (sentinel gate) and where to look (spatial attention) for word generation.



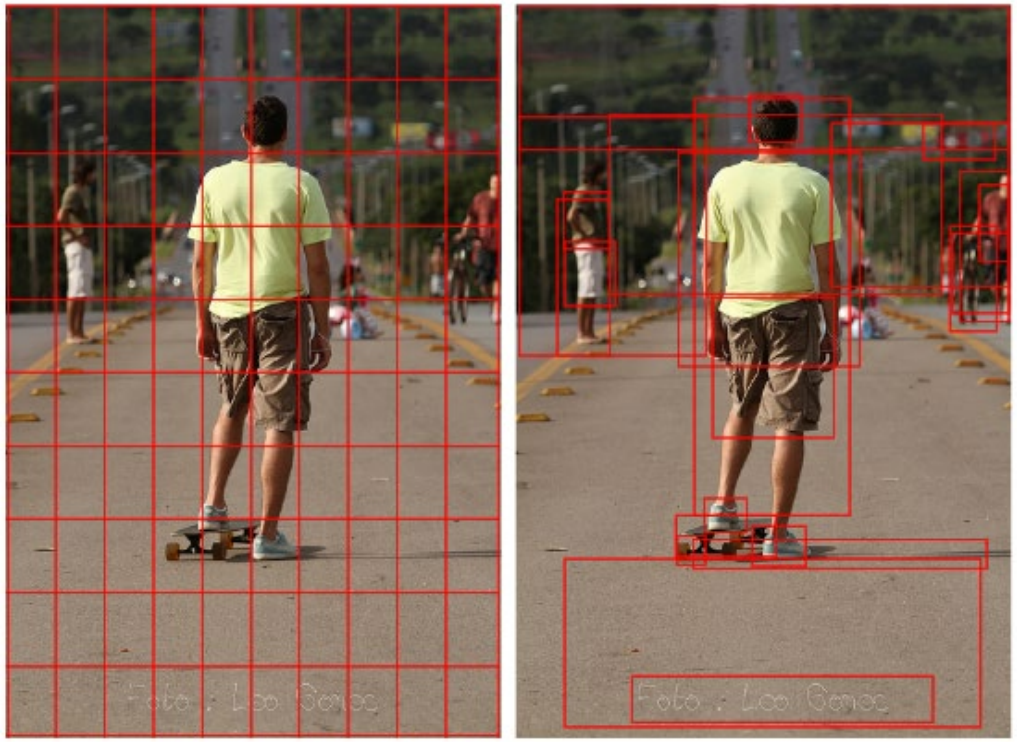
Knowing When to Look (Lu et al., 2017)

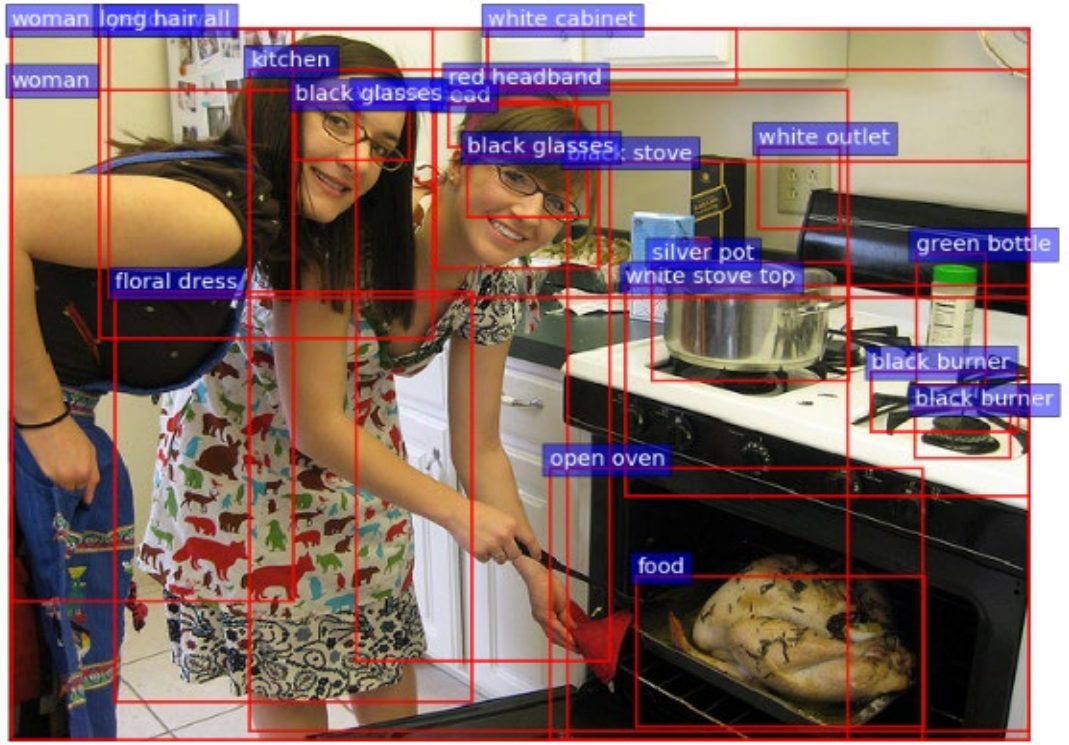
- Visualization of generated captions and image attention maps on COCO dataset

Source: Lu et al., (2017). Knowing When to Look: Adaptive Attention via A Visual Sentinel for Image Captioning

Bottom-up and Top-down attention (Anderson et al., 2018)

- Previous attention models operate on CNN features corresponding to a uniform grid of equally-sized image regions
- Bottom-up and Top-down enables attention to be calculated at the level of objects (or salient image regions)
- Features vectors extracted from Faster R-CNN are used





Source: Anderson et al., (2018). Bottom-Up and Top-Down Attention for Image Captioning and Visual Question Answering

Bottom-up and Top-down attention (Anderson et al., 2018)

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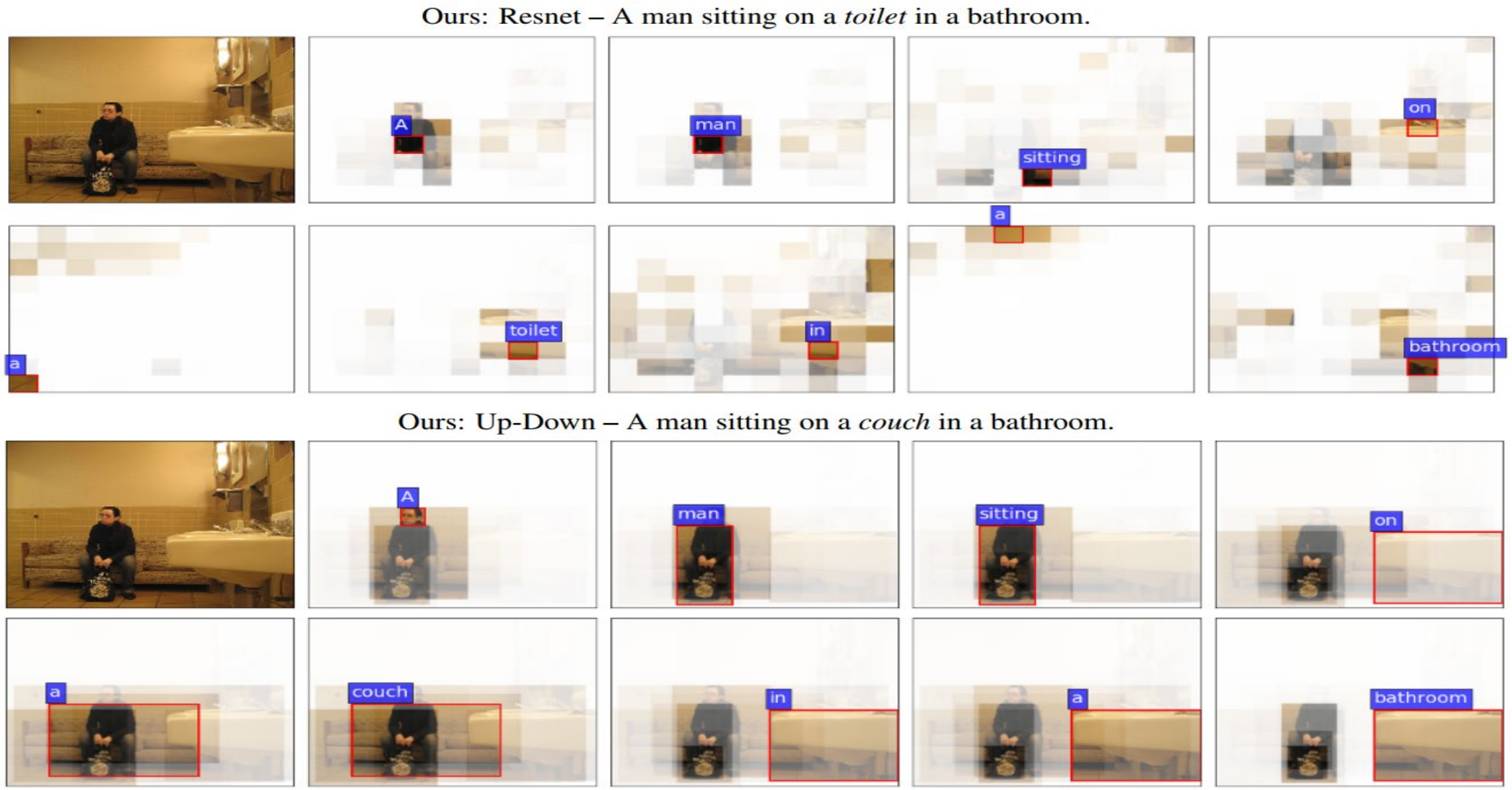


Source: Anderson et al., (2018). Bottom-Up and Top-Down Attention for Image Captioning and Visual Question Answering

And many more work …

- Show, Control and Tell: A Framework for Generating Controllable and Grounded Captions – Cornia M et al., CVPR 2019
- Pointing Novel Objects in Image Captioning, Li Y et al., CVPR 2019
- Describing like humans: on diversity in image captioning – Wang Q et al., CVPR 2019
- Length-Controllable Image Captioning – Deng C et al., ECCV 2020
- Transformer-based local-global guidance for image captioning – Parvin et al., 2023
- Show, tell and summarise: learning to generate and summarise radiology findings from medical images – Singh et al., Neural Computing & Applications, 2021.
- Medical image captioning via generative pretrained transformers – Selivanov et al. Scientific Reports, 2023

- Let's see Image captioning in action
  - https://milhidaka.github.io/chainer-image-caption/

Source: Awesome Image Captioning. https://githubmemory.com/repo/alibabadoufu/awesome-image-captioning

Visual Question Answering (VQA)

- Given an image, can our machine answer the corresponding questions in natural language?

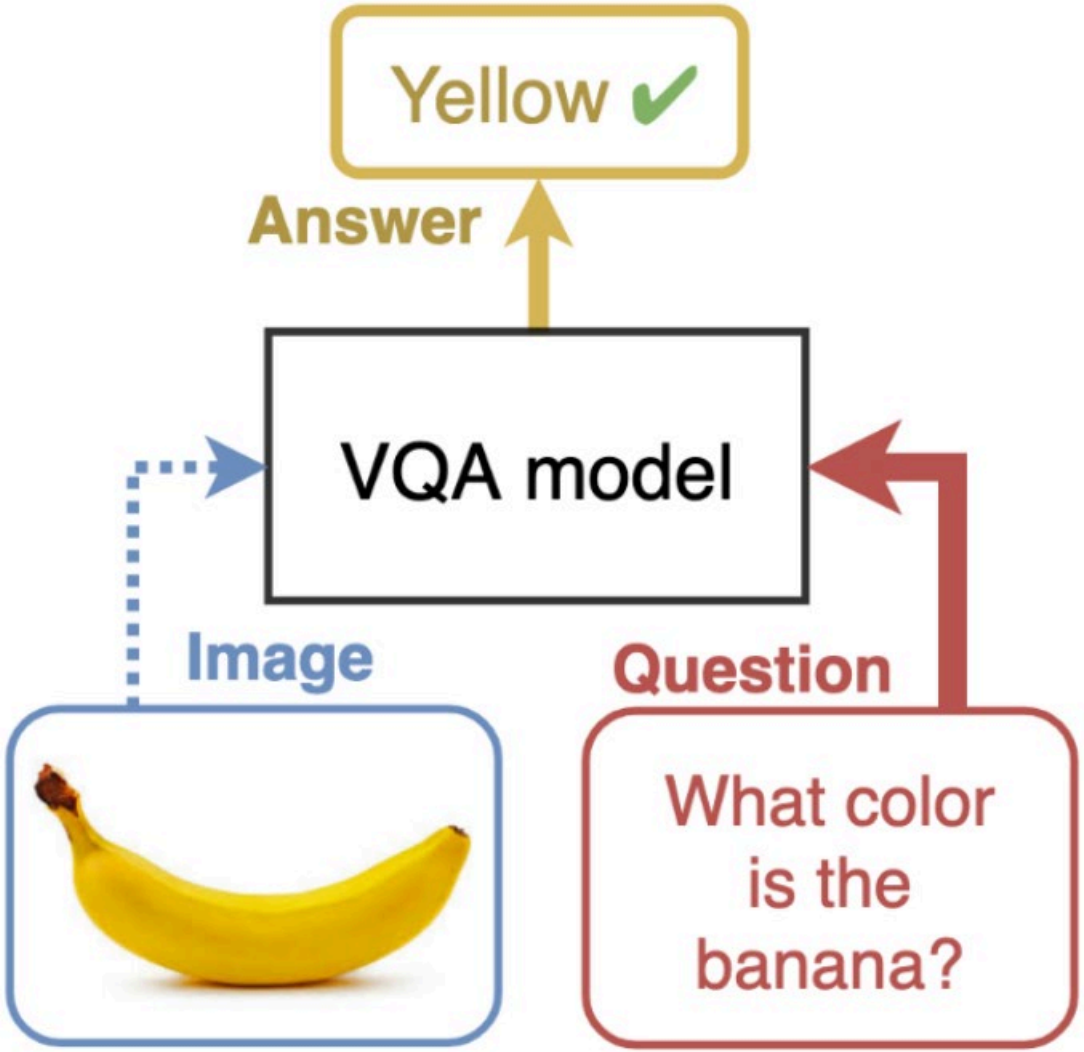


Image Credit: Corentin Dancette. https://cdancette.fr/2020/11/21/overview-bias-reductions-vqa/

VQA Dataset

➢

Who is wearing glasses?

man

woman

Where is the child sitting?

fridge

arms

Is the umbrella upside down?

yes

no

How many children are in the bed?

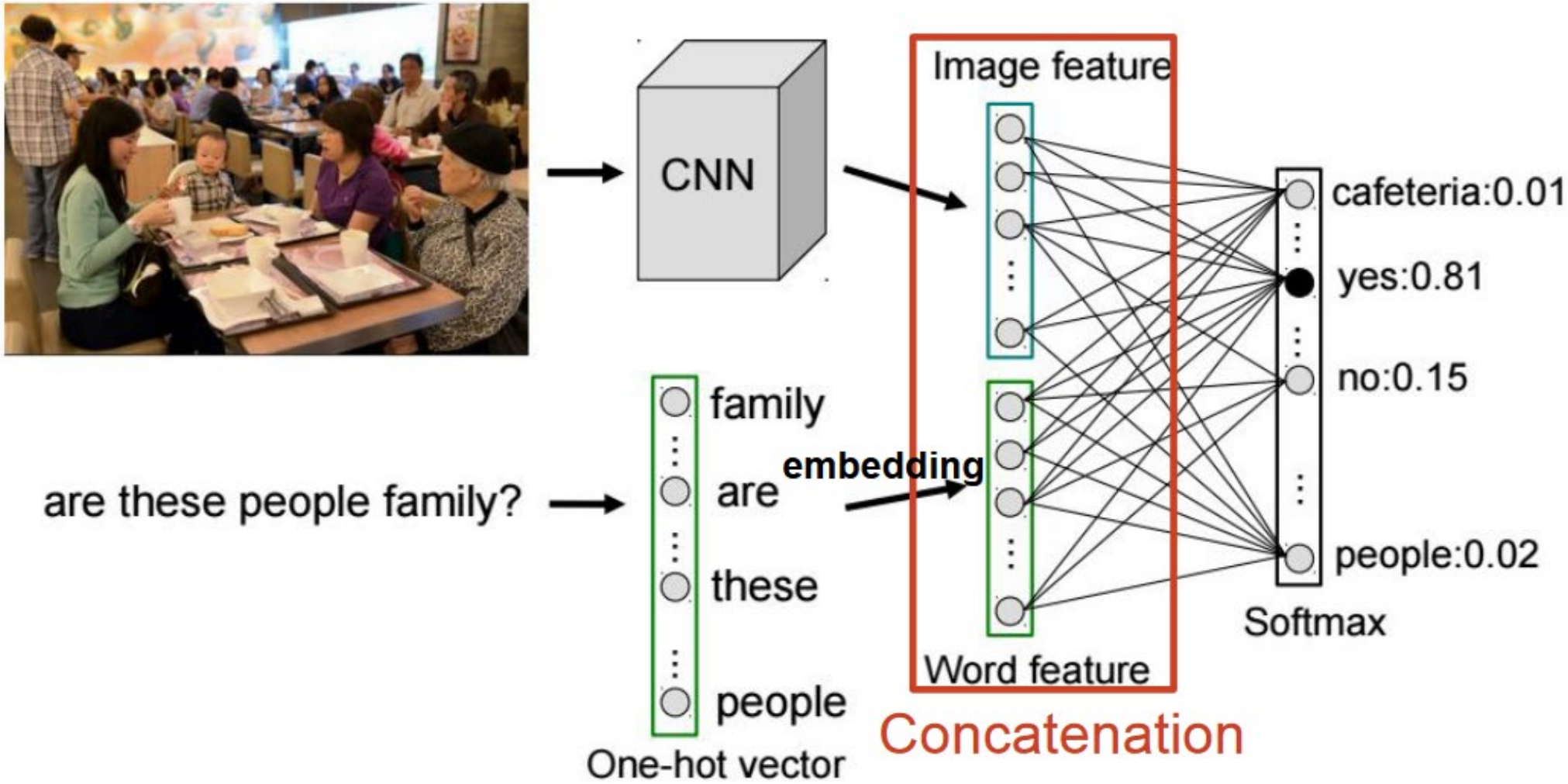
2

1

Source: Visual Question Answering. https://visualqa.org/

VQA Approach: Bag-of-words + Image feature (iBOWIMG)

- Combine image and word embeddings to predict answer



VQA Common Approach

- Combine CNN (for vision) and RNN (for language) to predict answer

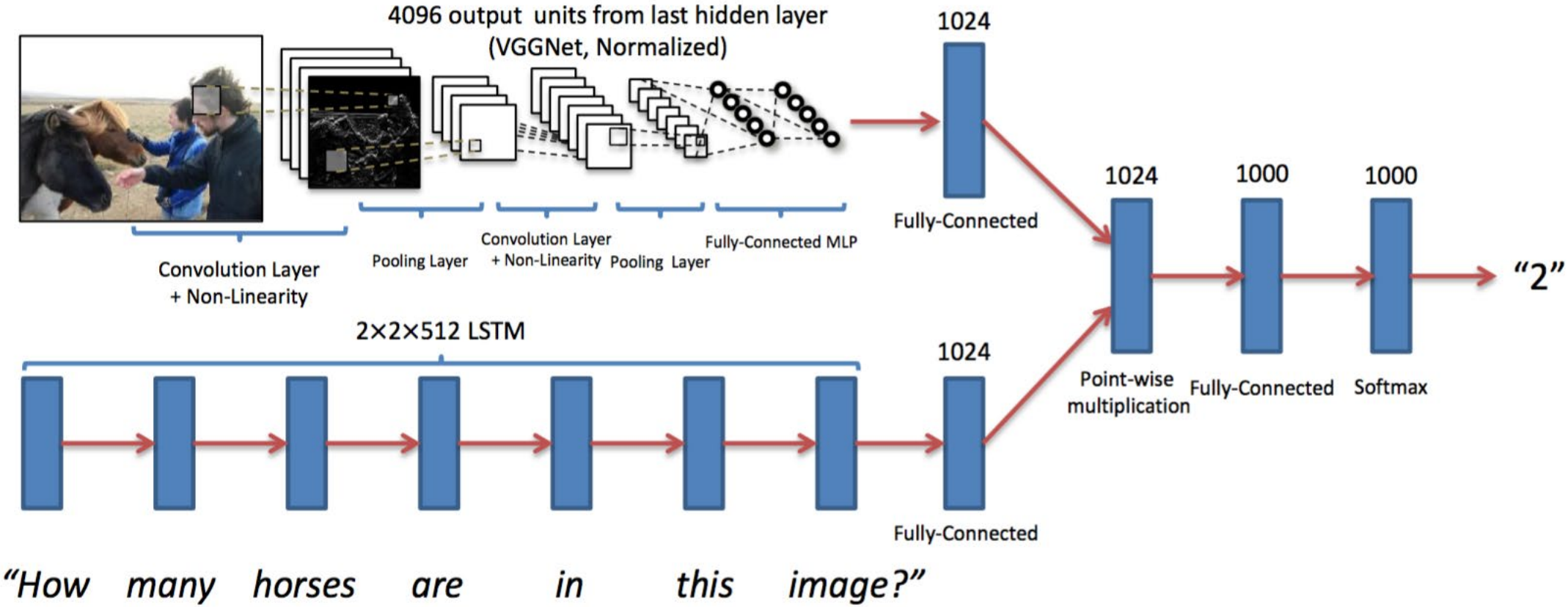


Image Credit: https://github.com/anantzoid/VQA-Keras-Visual-Question-Answering

VQA – set of problems

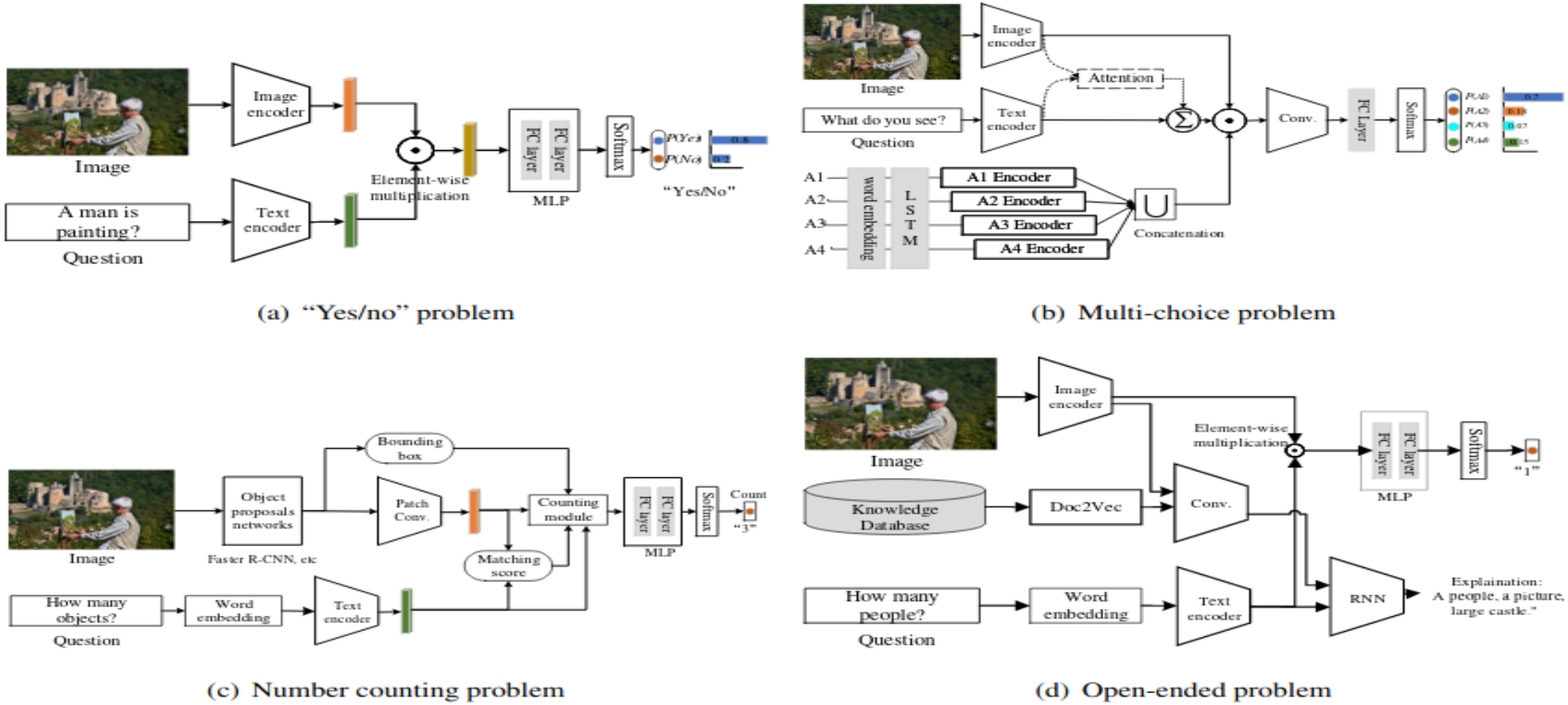
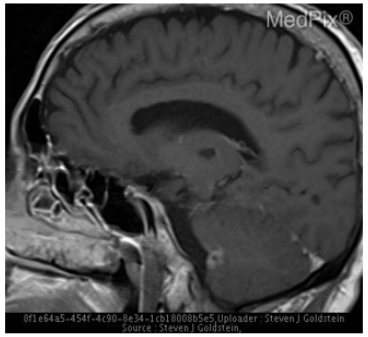


Figure 2 Common types of visual question answering. "Yes/No" problem and multi-choice problem can be regarded as a classification problem, while number counting problem and open-ended problem can be viewed as a caption generation problem.

Source: Chen et al., (2020). New Ideas and Trends in Deep Multimodal Content Understanding: A Review

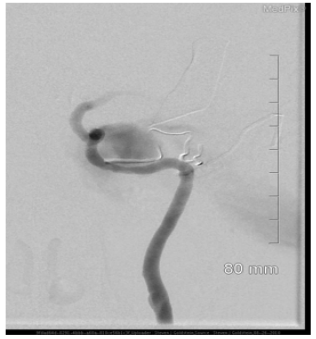
VQA in the Medical Domain

- Aims to create a system that can answer natural language questions based on a given medical image.
- VQA-Med 2019 Challenge dataset

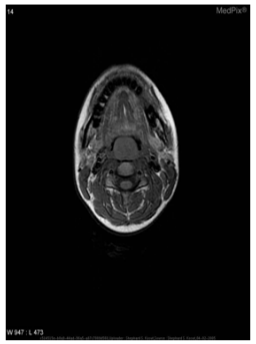


Q: What is the plane of this MRI?
A: Sagittal

Q: The CT scan shows what organ system?
A: Spine and contents



Q: With what modality is this image taken?
A: AN - angiogram

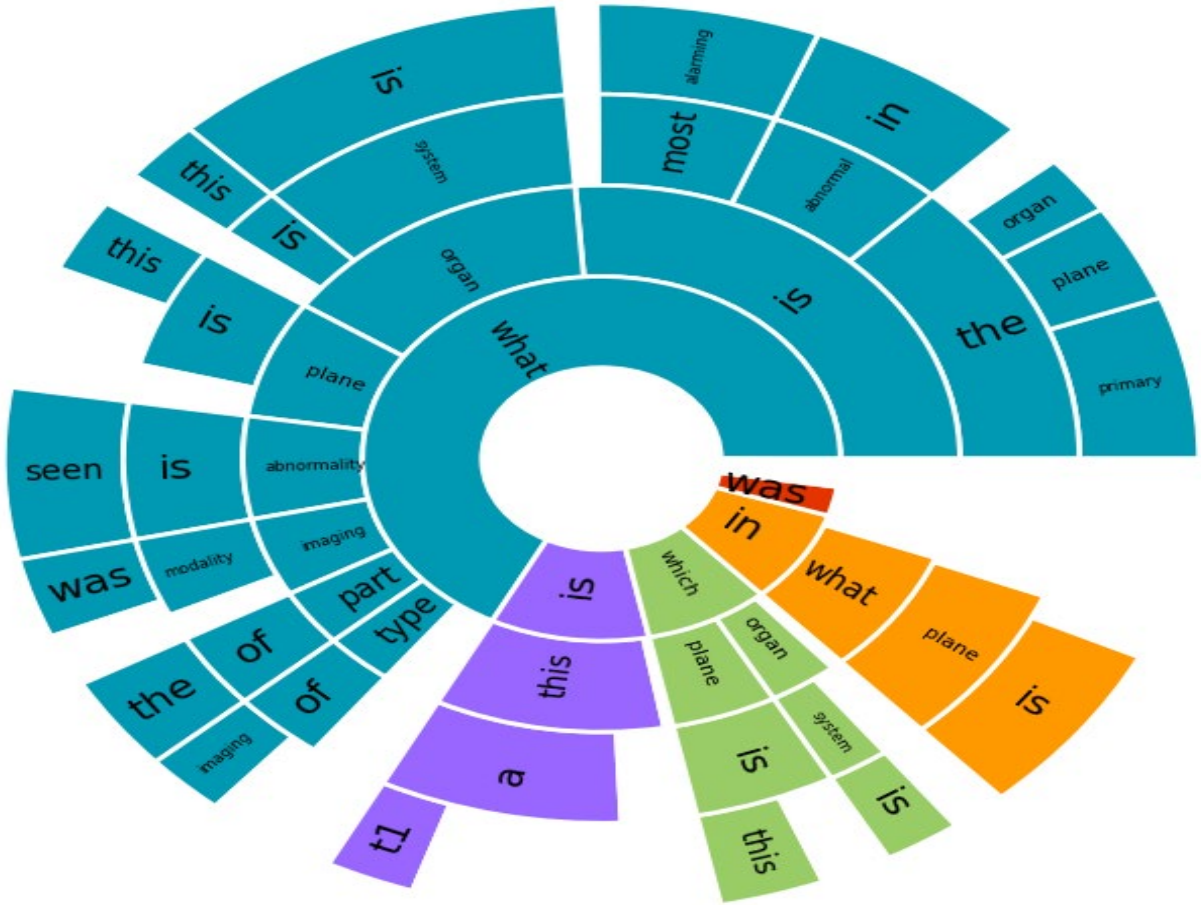


Q: What is most alarming about this MRI?
A: Schwannoma

Source: Canepa et al. (2023). Visual Question Answering in the Medical Domain. DICTA. 2023.

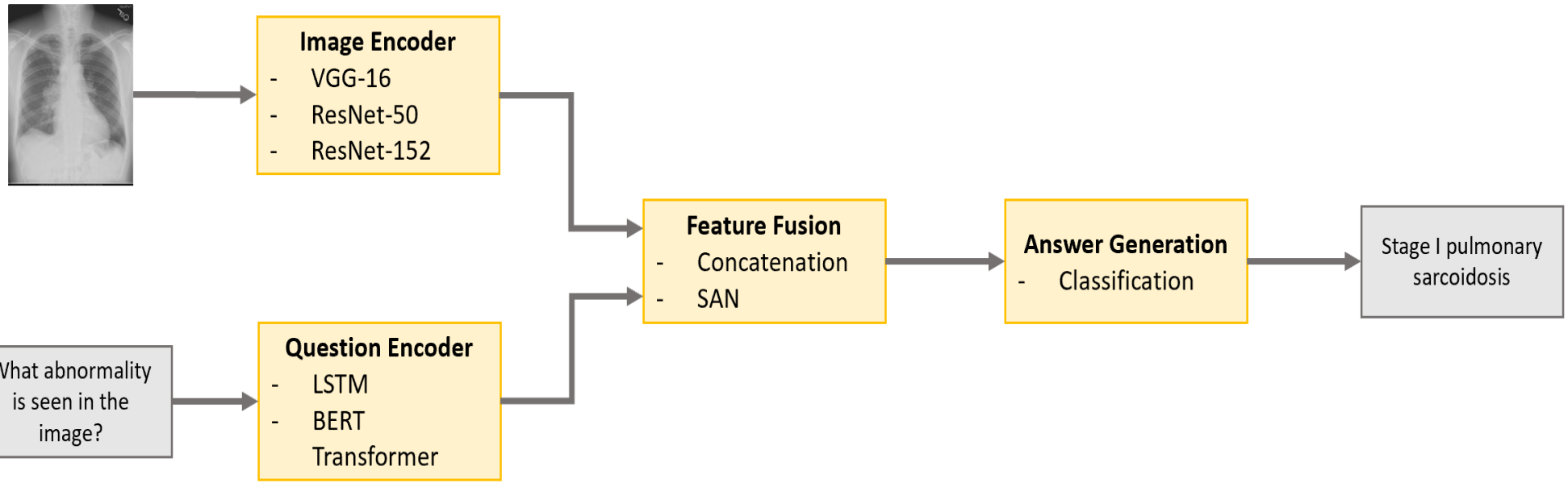
VQA-Med

- Most questions in VQA-Med 2019 dataset are “close-ended”
- More than 50% of answers consists of only one word, and more than 82% of answers have between one and three words.
- Best strategy is to do classification rather than generation



VQA-Med Methodology

- Contributions
  - Incorporating medical domain knowledge
    - Image encoder – applied self-supervised pretraining using Radiology Objects in COntext (ROCO) dataset
    - Question encoder – used BioBERT, pretrained on same tasks as BERT, but using the PubMed corpus
  - Evidence verification
    - Gradient Weighted Class Activation Map (Grad-CAM) for evidence verification



Results

- Test accuracy achieved by each model variation

Model Variation	Test Accuracy
VGG-16 + LSTM + Concatenation	0.56
ResNet-50 + LSTM + Concatenation	0.54
ResNet-152 + LSTM + Concatenation	0.53
VGG-16 + BERT + Concatenation	**0.60**
VGG-16 + BERT + SAN	0.58
VGG-16 + BioBERT + Concatenation	**0.60**
Pretrained VGG-16 + BERT + Concatenation	**0.60**

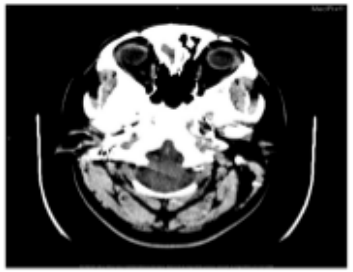
- Accuracy of the baseline vs. BERT model per category type

Model Variation	Baseline	+BERT
Modality	0.64	0.76
Plane	0.78	0.77
Organ	0.74	0.74
Abnormality	0.06	0.08
Overall	0.56	**0.60**

Source: Canepa et al. (2023). Visual Question Answering in the Medical Domain. DICTA. 2023.

Results

- Effect of using BERT vs. LSTM



Q: What imaging modality was used to take this image?
GT: CT with IV contrast
Baseline: Skull fracture from cell phone
+BERT: CT with IV contrast

(a) Category misclassification

Q: What was this image taken with?
GT: MR – PDW proton density
Baseline: Yes
+BERT: MR – PDW proton density

(b) Wrong answer type

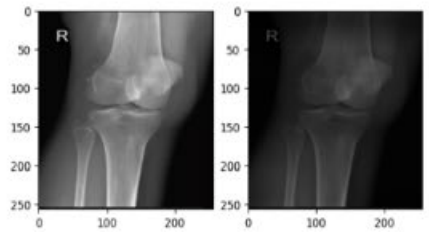
Q: Is this a contrast or noncontrast MRI?
GT: Noncontrast
Baseline: MR – flair
+BERT: Noncontrast

(c) Not choosing from options

Source: Canepa et al. (2023). Visual Question Answering in the Medical Domain. DICTA. 2023.

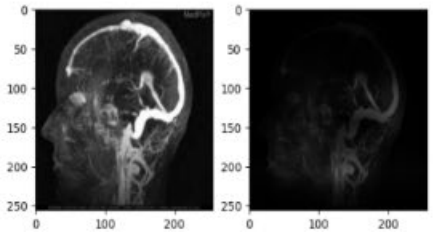
Evidence verification

- Attention distribution output by Stacked Attention Network (SAN) fusion method



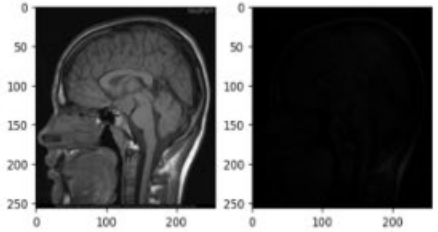
Q: What imaging modality is seen here?
GT: XR – plain film
A: XR – plain film

(a)



Q: What plane is demonstrated?
GT: Axial
A: Coronal

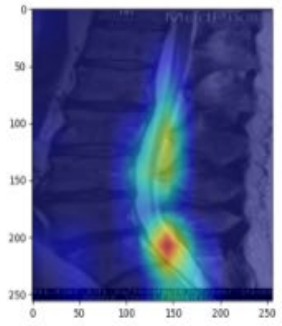
(b)



Q: What is most alarming about this MRI?
GT: Hypothalamic hamartoma
A: Meningioma

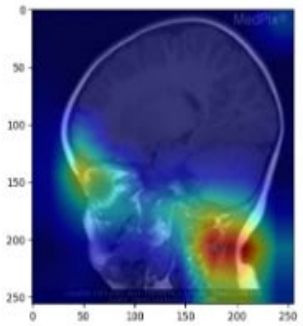
(c)

- Grad-CAM output



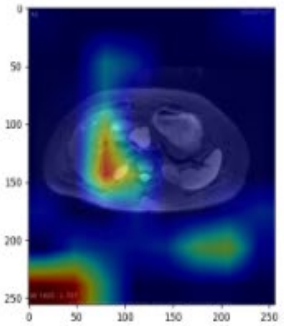
Q: Is this a T1 weighted image?
GT: No
A: No

(a)



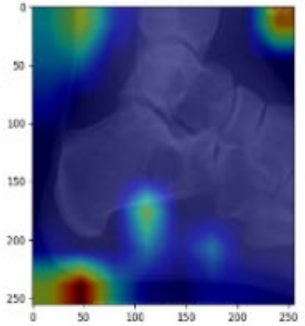
Q: In what plane is this MRI captured?
GT: Sagittal
A: Sagittal

(b)



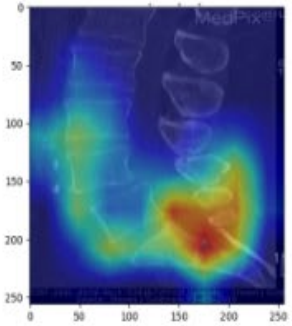
Q: What part of the body is being imaged?
GT: Gastrointestinal
A: Gastrointestinal

(c)



Q: What is abnormal in the X-ray?
GT: Chondroblastoma
A: Jones fracture and dancer's fracture

(d)



Q: What abnormality is seen in the image?
GT: Spondylolisthesis bilateral pars fracture
A: Spondylolysis

(e)

Source: Canepa et al. (2023). Visual Question Answering in the Medical Domain. DICTA. 2023.

Let’s see in action

- https://visualqa.org/visualize/
- https://demo.allennlp.org/visual-question-answering

Image Credit: https://github.com/anantzoid/VQA-Keras-Visual-Question-Answering

Visual Dialog

- Ability to hold a meaningful dialog with humans in natural language about visual content
- **Given an image** I, a **history of dialog consisting** of sequence of **question-answer pairs**, and a natural language **follow-up question**, the task for the machine is to **answer the question** in free-from natural language.

Image Credit: Visual Dialog. https://visualdialog.org/

Image Captioning vs. VQA vs. Visual Dialog

VQA

Q: How many people on wheelchairs ?

A: Two

Q: How many wheelchairs ?

A: One

Captioning

Two people are in a wheelchair and one is holding a racket.

Visual Dialog

Q: How many people are on wheelchairs ?

A: Two

Q: What are their genders ?

A: One male and one female

Q: Which one is holding a racket ?

A: The woman

Visual Dialog

Q: What is the gender of the one in the white shirt ?

A: She is a woman

Q: What is she doing ?

A: Playing a Wii game

Q: Is that a man to her right

A: No, it's a woman

Session Variables

Image Credit: Das et al., (2017) Visual Dialog. https://visualdialog.org/

Visual Dialog – Late Fusion Encoder

- Entire history H is concatenated and encoded by LSTM

Image I

Do you think the woman is with him?

Question Q_t

The man is riding his bicycle on the sidewalk. Is the man wearing a helmet? No he does not have a helmet on. ... Are there any people nearby? Yes there's a woman walking behind him.

t rounds of history (concatenated)

CNN

LSTM

LSTM

4096

512

512

512

Decoder

No I don't think they are together

Answer A_t

A fully-connected layer and tanh nonlinearity

Visual Dialog – Hierarchical Recurrent Encoder

- Each QA-pairs in history H separately encoded by the LSTM

Image I

Do you think the woman is with him?

Question Q_t

The man is riding his bicycle on the sidewalk.
Is the man wearing a helmet? No he does not have a helmet on.
How old is the man? He looks around 40 years old.
What color is his bike? It has black wheels and handlebars. I can't see the body of the bike that well.
Is anyone else riding a bike? No he's the only one.
Are there any people nearby? Yes there's a woman walking behind him.

t rounds of history

{(Caption), (Q_1,A_1), ..., (Q_{t-1}, A_{t-1})}

CNN

LSTM

$I+Q_t$

LSTM

H_{t-5} H_{t-4} H_{t-3} H_{t-2} H_{t-1} H_t

$I+Q_{t-1}$ $I+Q_{t-2}$ $I+Q_{t-3}$

512 512

t t-1 t-2 t-3 t-4 t-5

GRU

Decoder

No I don't think they are together

Answer A_t

Each QA-pair in dialog history is independently encoded by another LSTM with shared weights

The image-question representation, computed for every round from 1 through t , is concatenated with history representation from the previous round and constitutes a sequence of question-history vectors

Image Credit: Das et al., (2017) Visual Dialog. https://visualdialog.org/

Visual Dialog – Hierarchical Recurrent Encoder

- Compute inner product of question vector with each history vector to get scores over previous rounds, which are fed to a SoftMax to get attention-over-history probabilities.

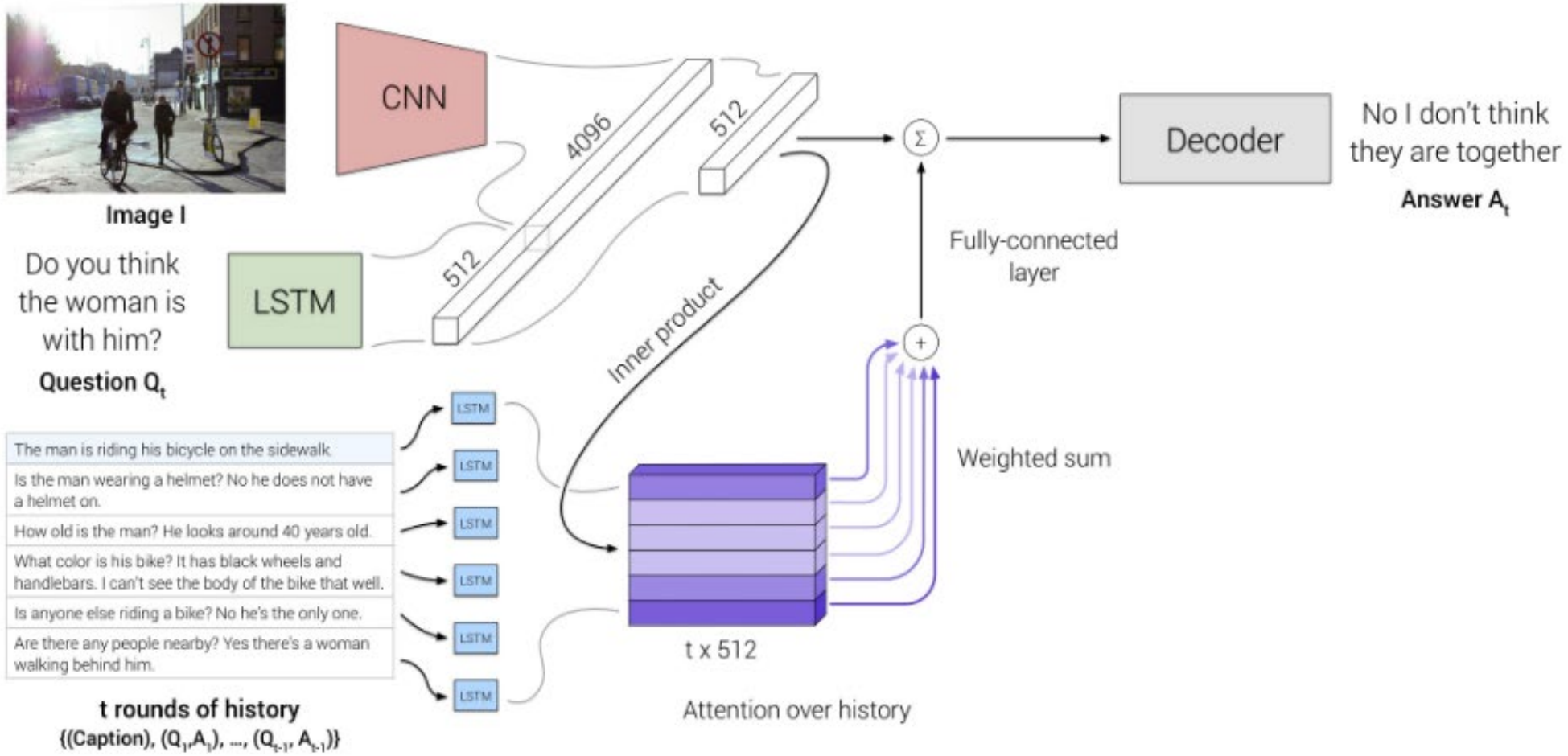


Image Credit: Das et al., (2017) Visual Dialog. https://visualdialog.org/

Improving Visual Dialog (and few examples)

- Generates more diverse, image relevant and fluent dialog.

Image + Caption	GT dialog (Das et al., 2017a)	Q-BOT-A-BOT dialog	Diverse-Q-BOT-A-BOT dialog
	what color is the cutting board? blue how big is it about the size of a regular laptop screen how many carrots are there ? 4 are they the orange kind ? 2 are orange , 2 are white what kind of cell phone is it ? a samsung can you see any text on the screen ? a recipe for UNK UNK soup do you see the room ? just the counter are there people ? not visible what color is the counter ? white	is the photo in color ? no how many people do you see ? no people is this a close up ? no is this a close up ? zebra is is this a close up ? no is this a close up ? no is this a close up ? no is this a close up ? no is this a close up ? no is this a close up ? no	is the photo in color ? 1 picture is in color is the photo close up ? black and white is the photo in color ? no it 's black and white is it a close up ? no it 's a close up of the cake can you tell what brand it is ? no i ca n't see the brand can you tell if it 's a male or female ? no i ca n't tell can you tell if it 's a male or female ? no i ca n't tell is this in a kitchen ? nope it 's in a home are there any utensils ? no are there any utensils ? nope
a cutting board with carrots next to a cell phone.			
	is the field large ? yes is the grass green or brown ? green can you see a barn ? no can you see a fence ? no can you see a water supply ? yes can you see any people ? no can you see trees ? yes can you see mountains in the background ? no is the grass tall or short ? short	what color are the cows ? they are brown and white how many cows are there ? 4 what color are the cows ? they are brown and white can you see the sky ? it is not visible do you see any trees ? i do not see any trees can you see the sky ? green sky are there any clouds ? the sky is not visible how many cows are there ? 2 what color are the cows ? the cows are brown and white what color are the cows ? they are brown	do you see any people ? 1 do you see a fence ? a small 1 how many cows are there ? 5 what color are the cows ? black and white can you see the sky ? some can you see the sky ? nope are there any other animals ? not that i can see can you see the sky ? not at all are there any trees ? in the background can you see the sky ? not at all
many brown and black cows standing in the grass			
	what type of building ? may be part of a zoo how many elephants ? about 4 is it sunny ? clear day , yes any trees ? yes what color is the building ? dark grey are there other animals ? no are there any people ? yes what are they wearing ? shorts and shirts how many ? 3	how many elephants are there ? ca n't tell what color are the elephants ? ca n't tell how many elephants are there ? ca n't tell what color is the fence ? i ca n't tell can you see the sky ? i ca n't see the sky are there any trees ? just a few does this look like a zoo ? 1 of them is are there any people ? nothing in the picture how many elephants are there ? just 1 can you see the sky ? just a little	how many elephants are there ? 1 any people ? ca n't see any male or female ? not sure what is the elephant doing ? just standing there male or female ? there are 2 males and 1 female can you see the sky ? 1 of it what color is the building ? just a black and white picture do you see any trees ? there are trees in the background are there any other animals ? red and white do you see any trees ? i see some in the background
many elephants standing in an enclosure near a building			
	is the photo in color ? yes is there humans in the photo ? no is there any animals in the photo ? no what color are the walls ? tan what color is the sink ? white is there any towels ? no is there any pictures on the wall ? no what color is the tub ? white can you see the floor ? no	is the photo in color ? 5 of them are are there any people ? it 's a close up so i ca n't see any people what color is the sink ? about the same color as the toilet do you see a mirror ? no what color is the sink ? yes it is white what color is the sink ? yes it is white what shape is the mirror ? yes , it 's a rectangle are there any towels ? he 's on a towel rack are there any towels ? i do n't see any towels are there any towels ? i do n't see any towels	is the photo in color ? no is there any people ? 5 what color walls ? i ca n't see the walls is there a mirror ? yes is there a mirror ? yes is there a mirror ? yes are the walls seen ? no what color are the walls ? no walls what is the floor made of ? yes what color is the floor ? i ca n't see the floor
a reflection of the tub is in the bathroom mirror along with the sink , you can see all the room			

Source: Murahari et al., (2019) Improving Generative Visual Dialog by Answering Diverse Questions.

Many more tasks at CV+NLP

- Vision-Language Navigation (VLN)

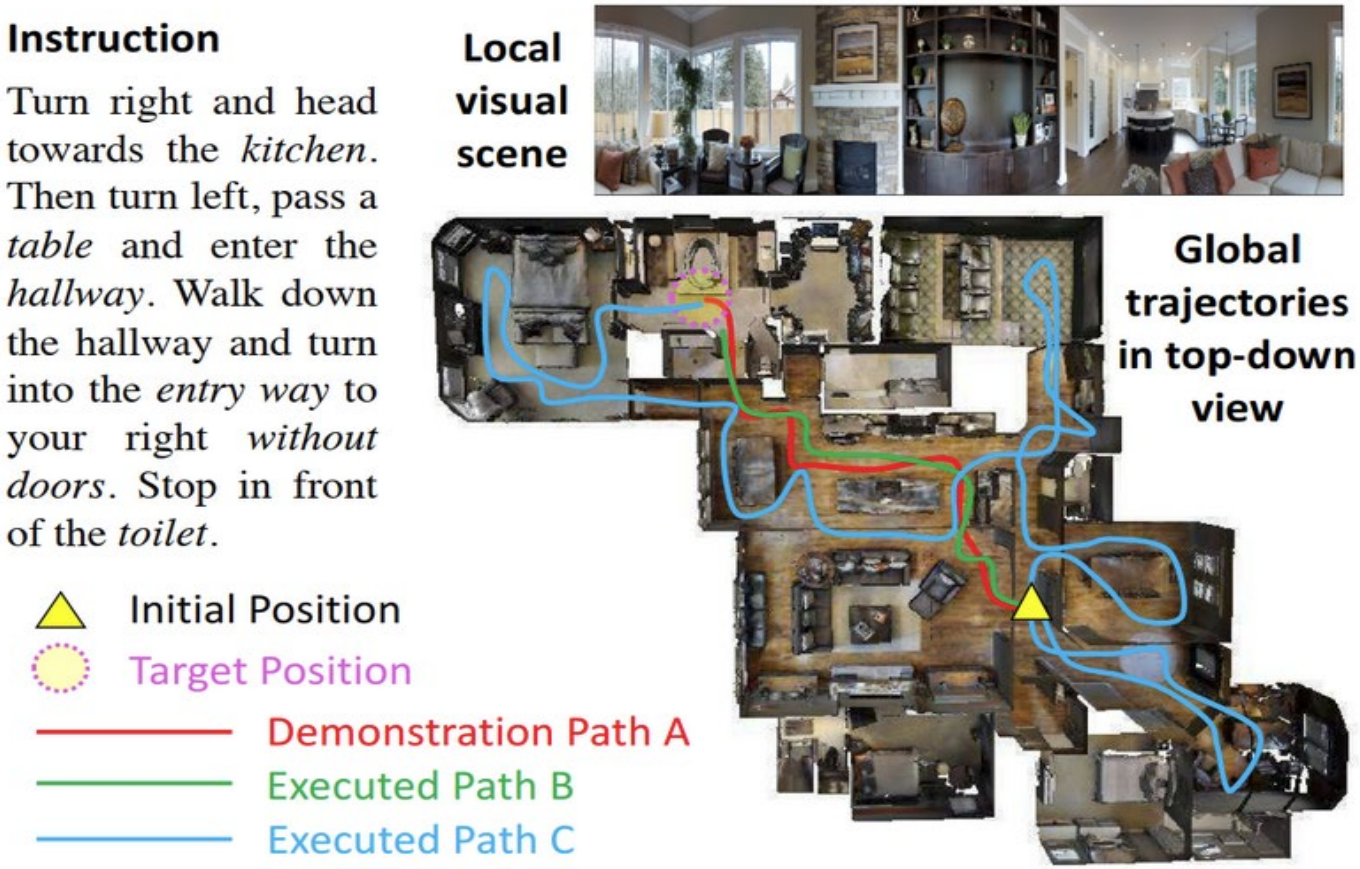


Figure 1: Demonstration of the VLN task. The instruction, the local visual scene, and the global trajectories in a top-down view. The agent does not have access to the top-down view. Path A is the demonstration path following the instruction. Path B and C represent two different paths executed by the agent. Figure credit: Wang et al. (2019).

Source: Wang et al. (2019) Reinforced Cross-Modal Matching and Self-Supervised Imitation Learning for Vision-Language Navigation

Many more tasks at CV+NLP

- Visual grounding for referring expressions
  - Grounding an utterance to refer to something or someone in image

(a) (b) (c)

Fig. 1: Interactive visual grounding of referring expressions. (*a*) Ground self-referential expressions. (*b*) Ground relational expressions. (*c*) Ask questions to resolve ambiguity. Red boxes indicate referred objects. Blue dashed boxes indicate candidate objects. See also the accompanying video at http://bit.ly/INGRESSvid.

- Let's see video in action: http://bit.ly/INGRESSvid

Source: Sridhar et al. (2018). Interactive Visual Grounding of Referring Expressions for Human-Robot Interaction

Many more tasks at CV+NLP

- Fun stuff: Comic books

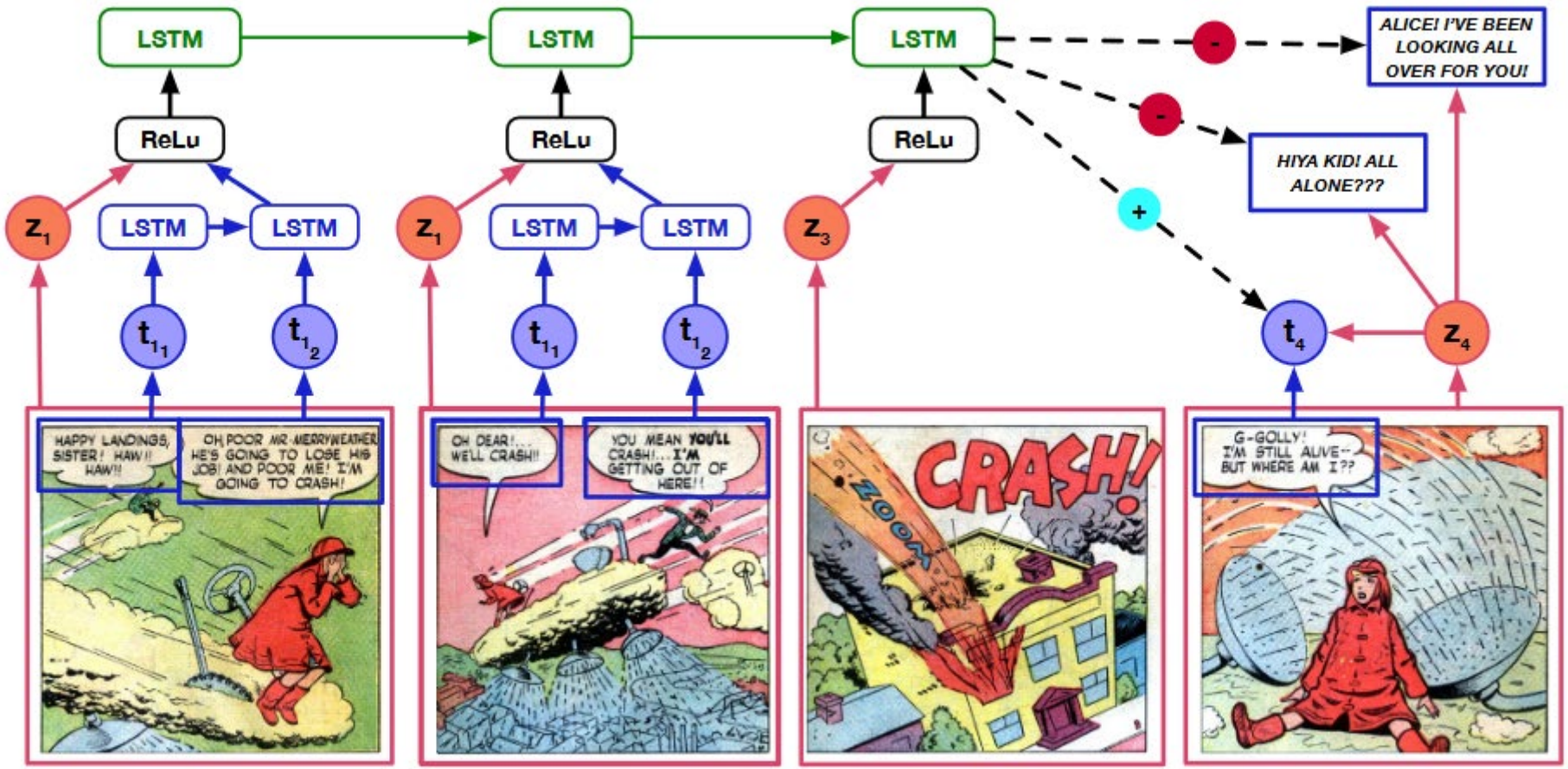
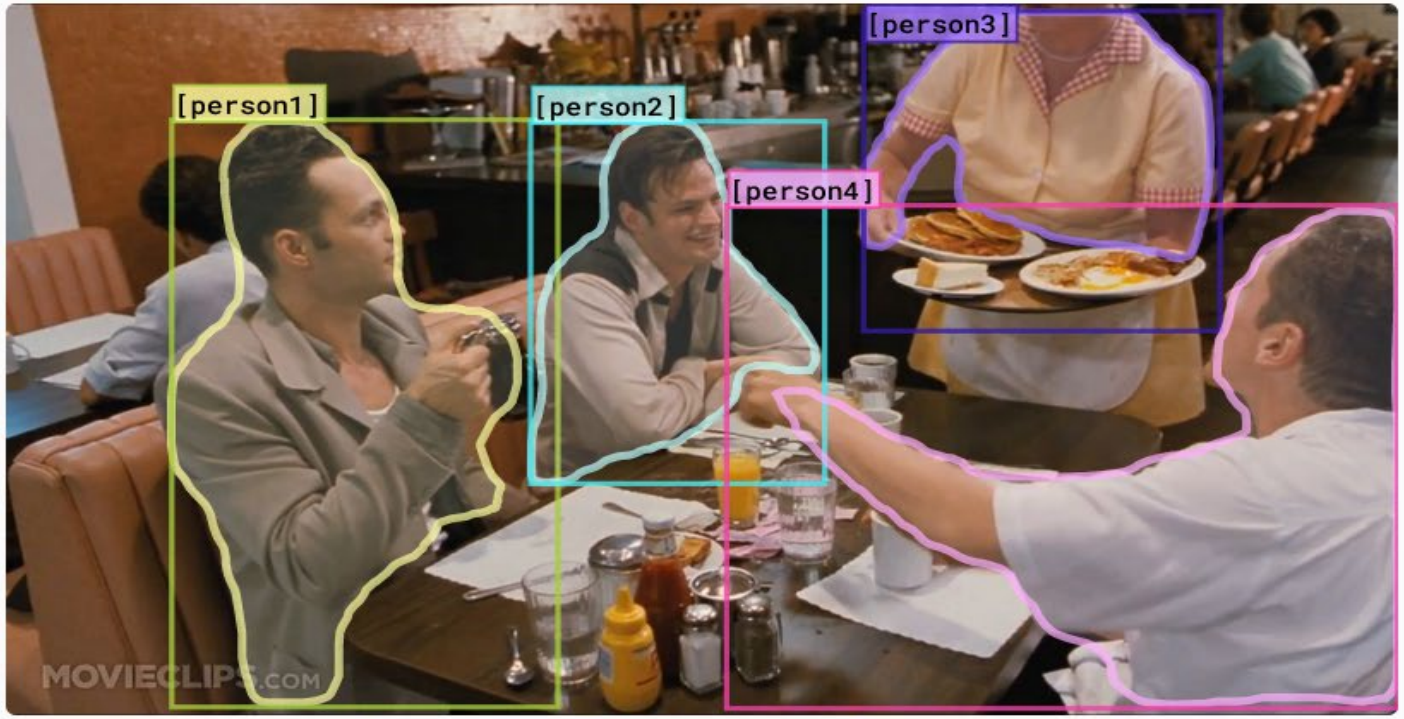


Figure 5. The **image-text** architecture applied to an instance of the *text cloze* task. Pretrained image features are combined with learned text features in a hierarchical LSTM architecture to form a context representation, which is then used to score text candidates.

Source: Iyyer et al. (2017) The Amazing Mysteries of the Gutter: Drawing Inferences Between Panels in Comic Book Narratives

Many more tasks at CV+NLP

- From Recognition to Cognition: Visual Commonsense 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.

Source: Zellers et al. (2019) From Recognition to Cognition: Visual Commonsense Reasoning

Summary

- Vision + Language: Help us to understand human brain functioning better
- Visual Turing Test for modern AI systems
- A step towards Artificial General Intelligence (AGI)
- Variety of applications:
  - Helping visually-impaired people
  - Early child education
  - Personal assistants
  - Robot navigation
  - Video surveillance systems
  - Search engines

Questions?

If you feel fascinated and want to get involved in research, feel fee to reach out at sonit.singh@unsw.edu.au