SDSC Summer Institute
Deep Learning

SDSC SAN DIEGO SUPERCOMPUTER CENTER

UC San Diego

U-Net and LSTM

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U-Net

Image Segmentation

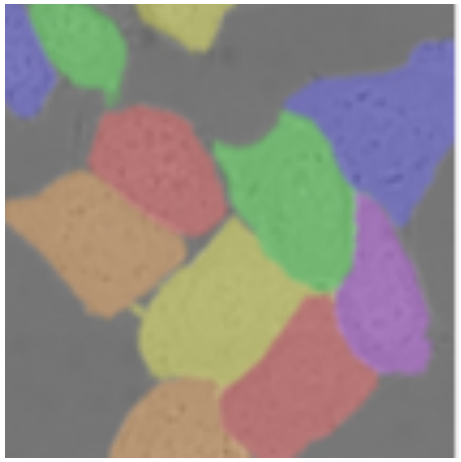
- **Dividing image into multiple salient image regions**
  - Assign label to every pixel in image
  - Pixels with same label are similar

https://medium.com/@keremturgutlu/semantic-segmentation-u-net-part-1-d8d6f6005066

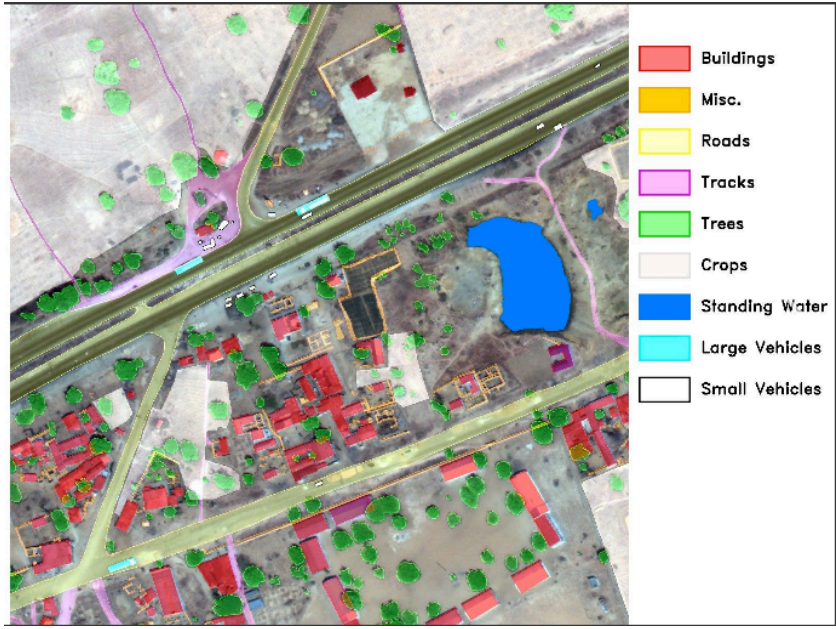
U-Net

- **Used for image segmentation**
- **Architecture**
  - Encoder-decoder network
  - Contracting part of network performs feature extraction
    - Encoding path
  - Expansion part of network performs segmentation
    - Decoding path

U-Net Applications

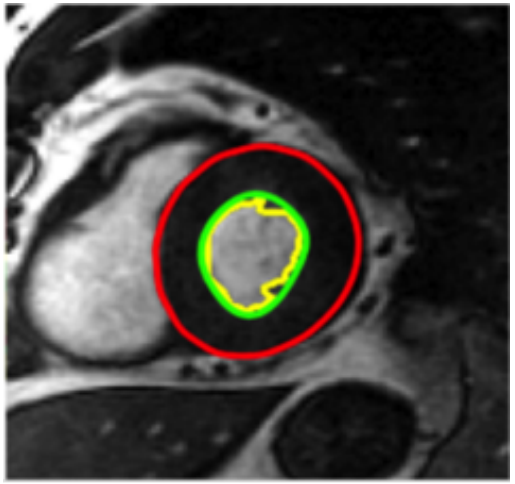


Biomedical Segmentation



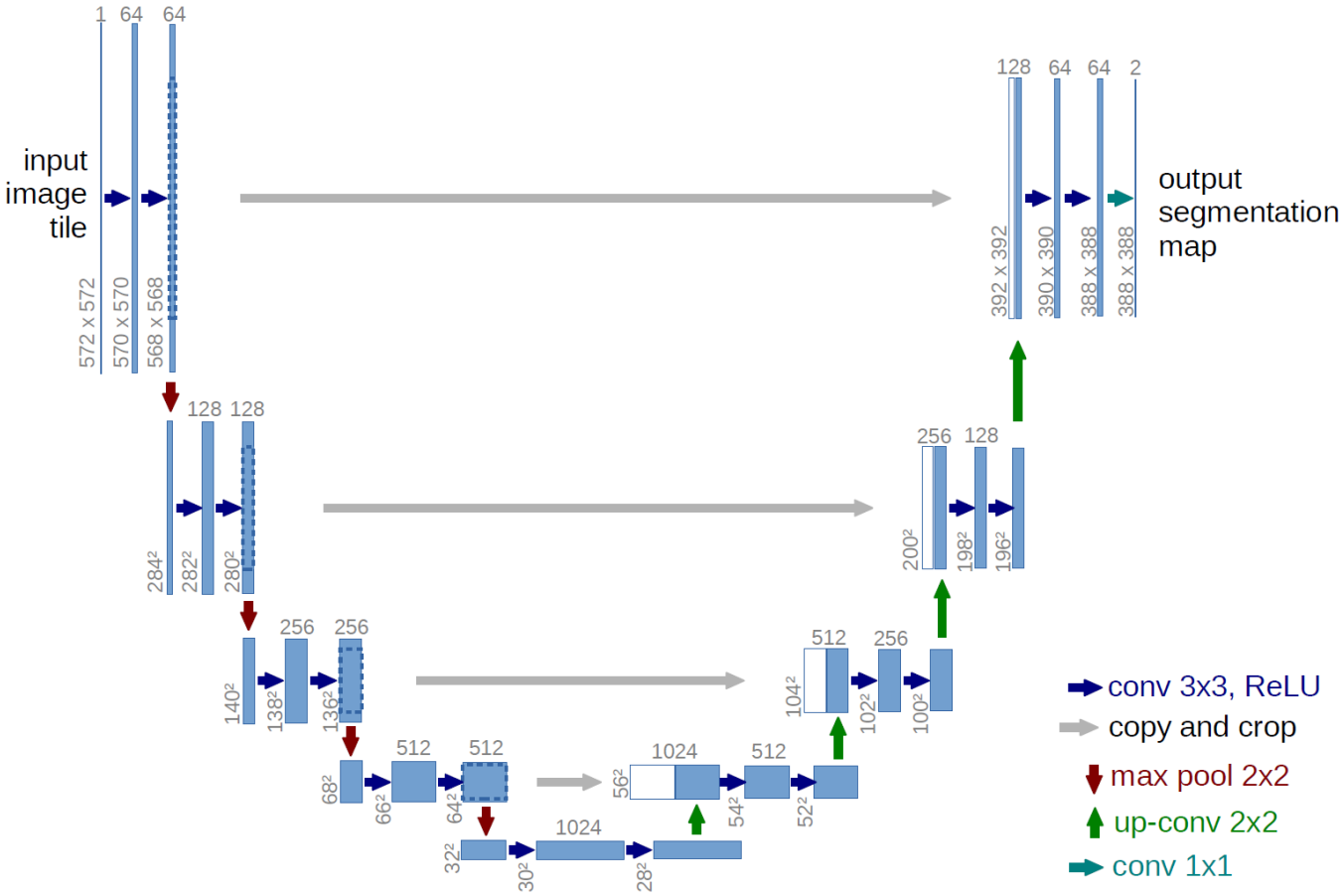
Satellite Image Processing

Object Detection



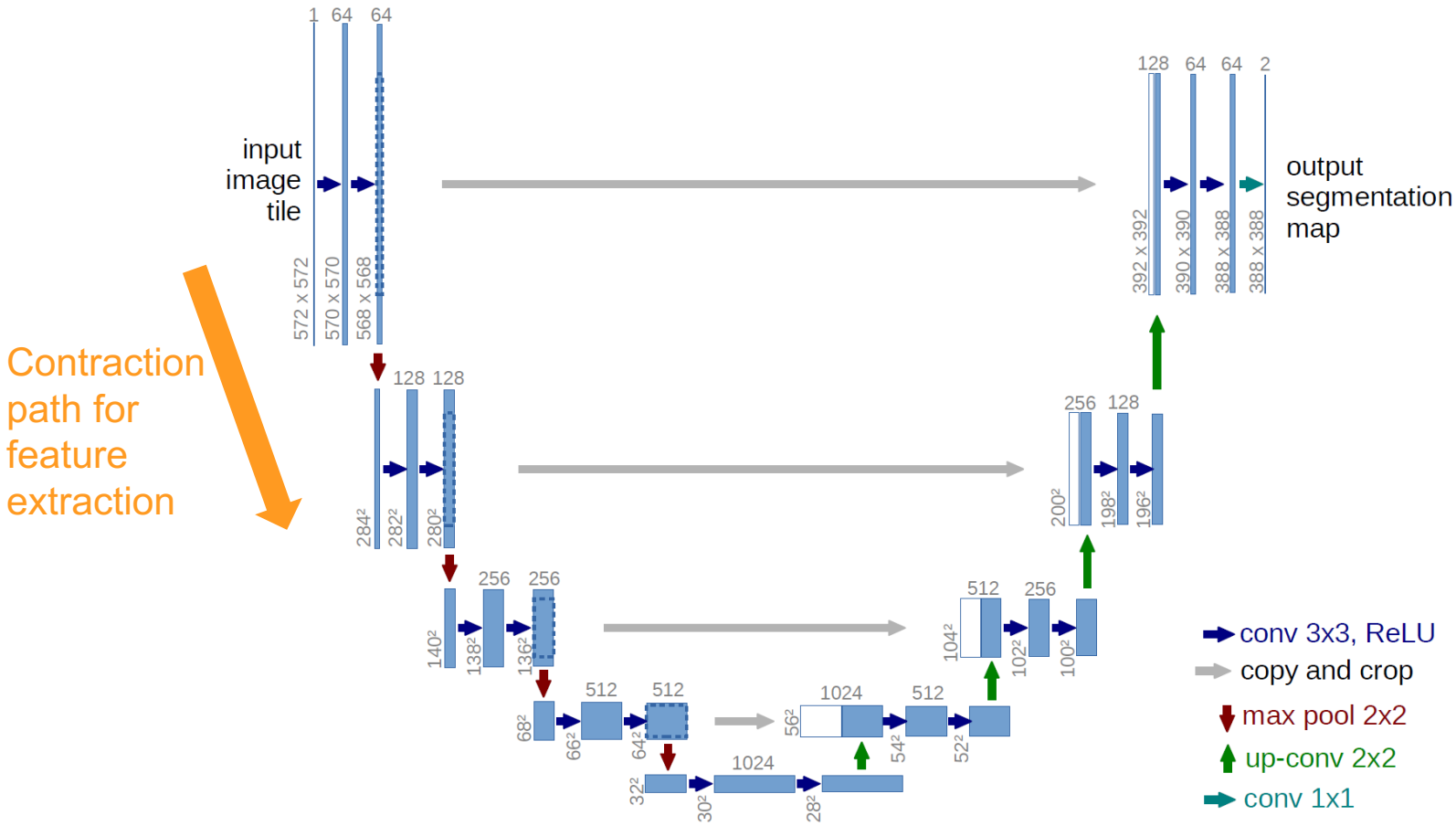
Medical Image Analysis

U-Net Architecture



https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/

U-Net Architecture



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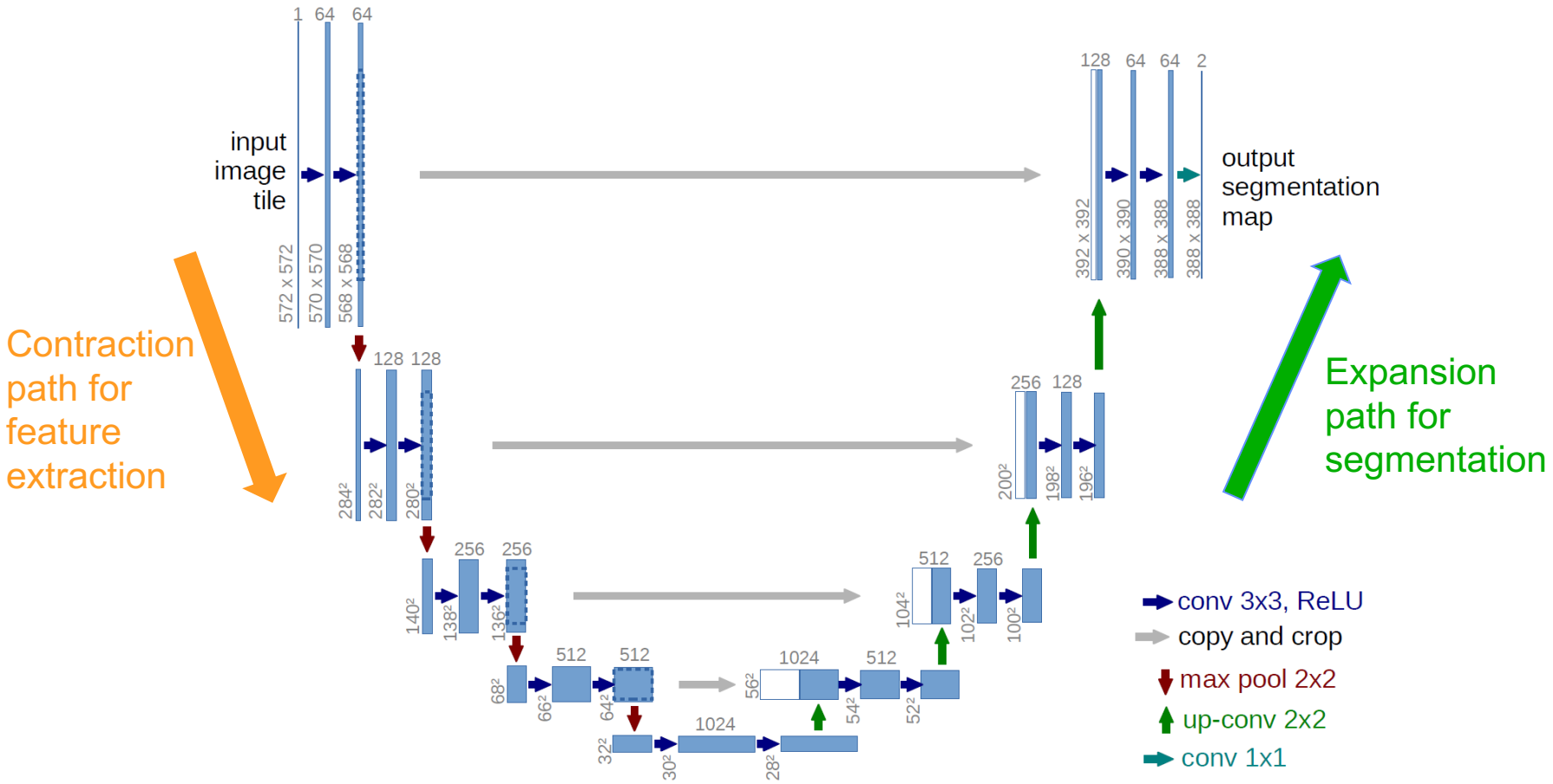
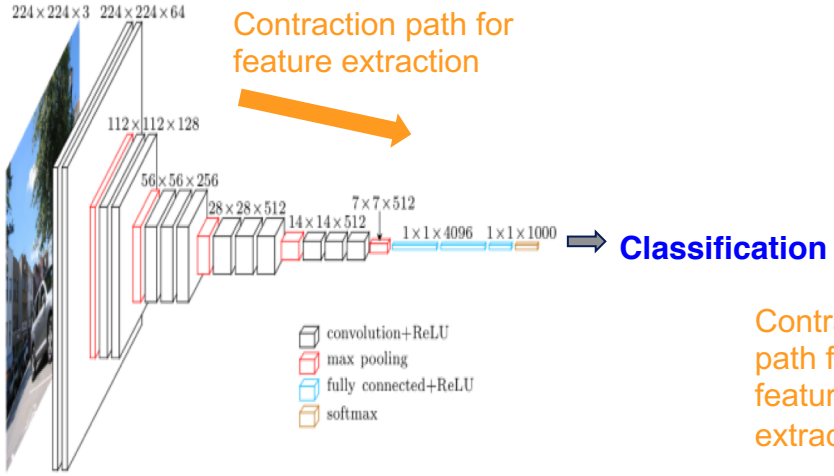
U-Net Architecture



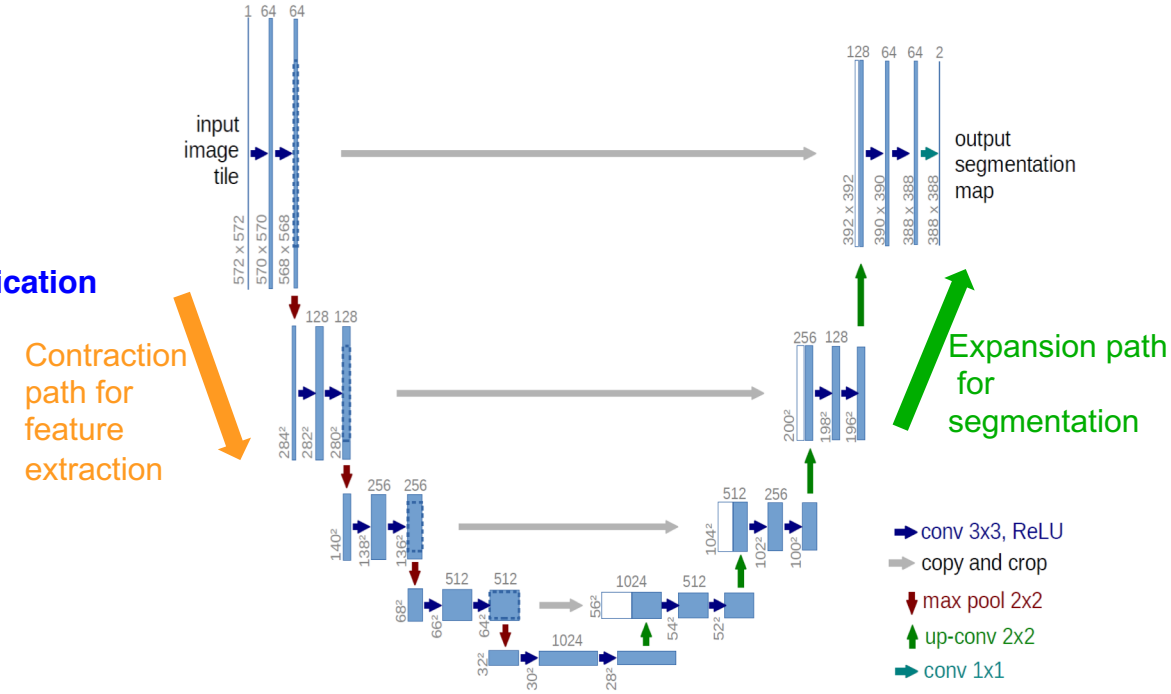
https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/

U-Net Architecture

VGG16 CNN Architecture



U-Net Architecture



https://spark-in.me/post/unet-adventures-part-one-getting-acquainted-with-unet.

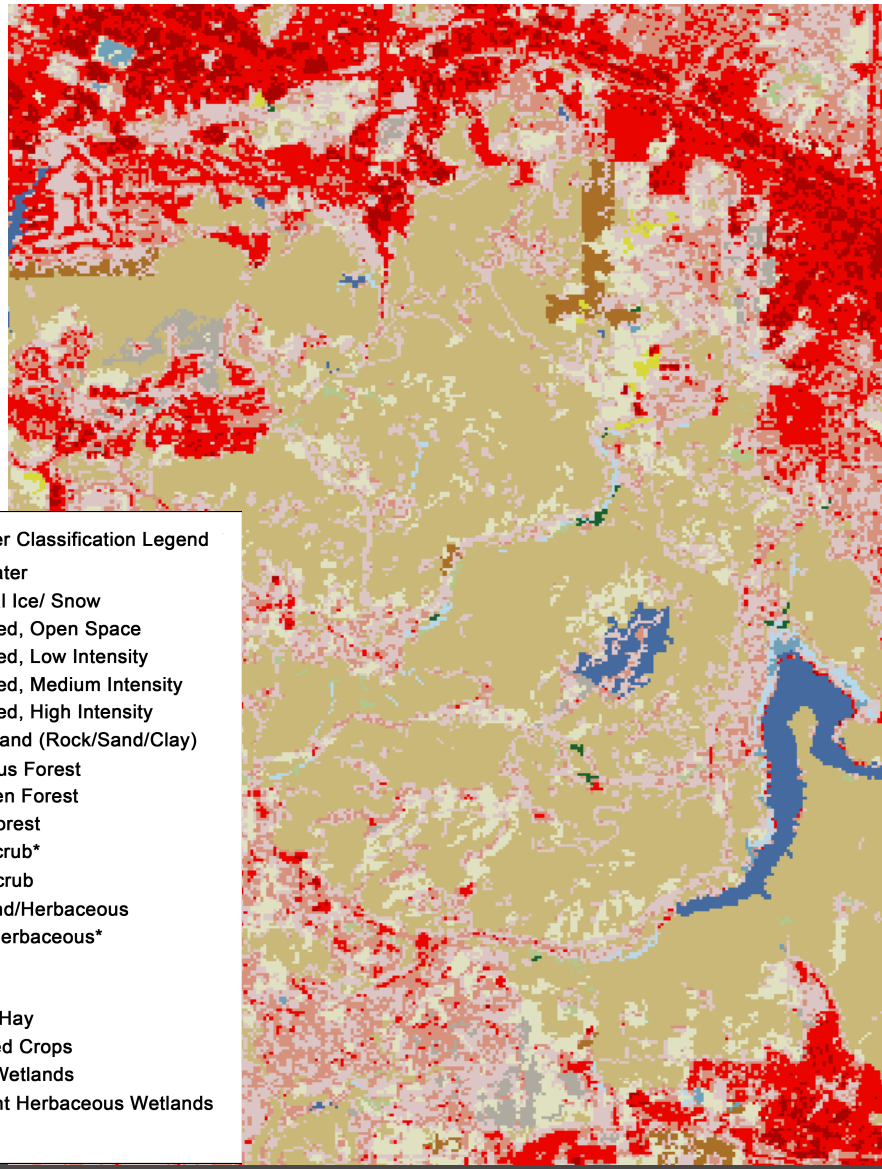
https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/

U-Net Use Case

Satellite Image Analysis

- **Goal**
  - Generate land cover maps from satellite imagery
- **Motivation**
  - Land data products are critical for many applications
  - Current land data products are released every few years
  - Want to generate land data products at scale, as needed, and based on up-to-date data
- **Approach**
  - Use deep/machine learning techniques to extract and analyze features from satellite imagery

Land Cover Map Example



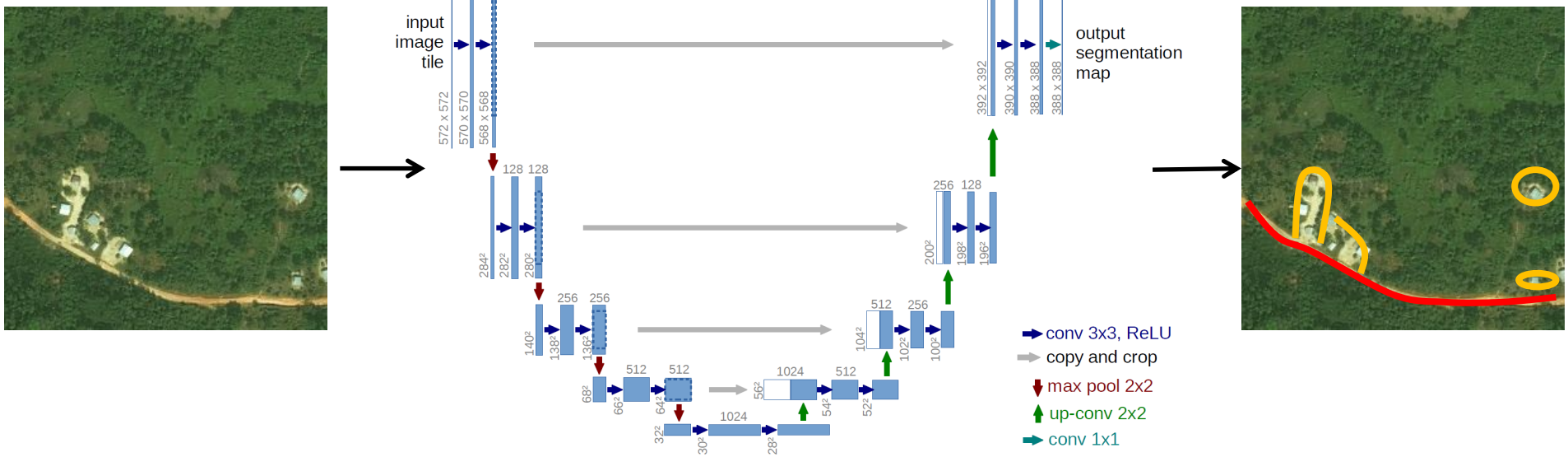
NLCD Land Cover Classification Legend

- 11 Open Water
- 12 Perennial Ice/ Snow
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land (Rock/Sand/Clay)
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 51 Dwarf Scrub*
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 72 Sedge/Herbaceous*
- 73 Lichens*
- 74 Moss*
- 81 Pasture/Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

* Alaska only

Deep Learning

U-Net



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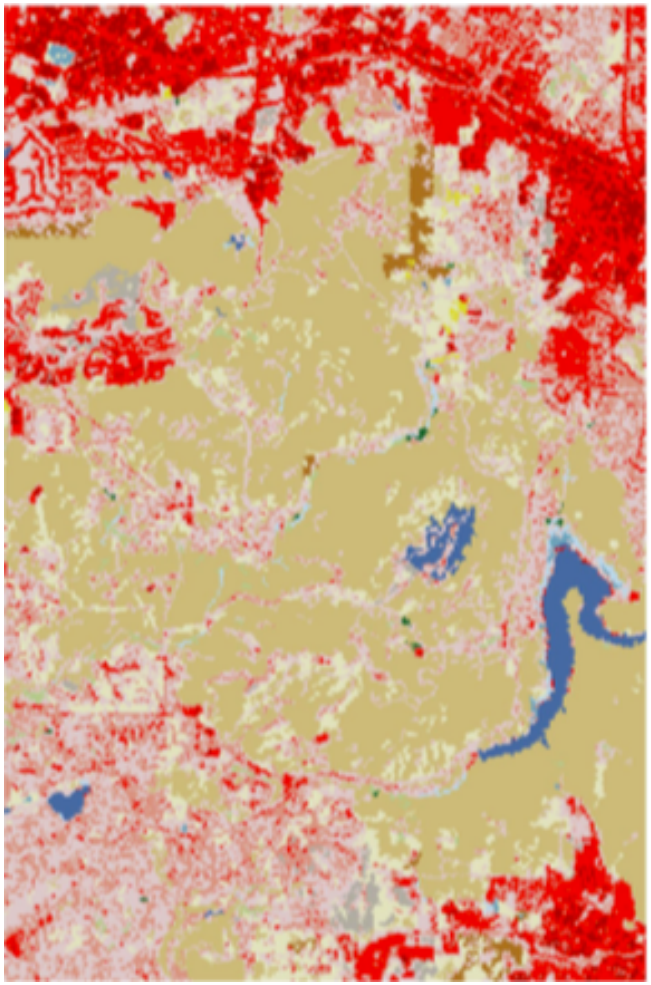
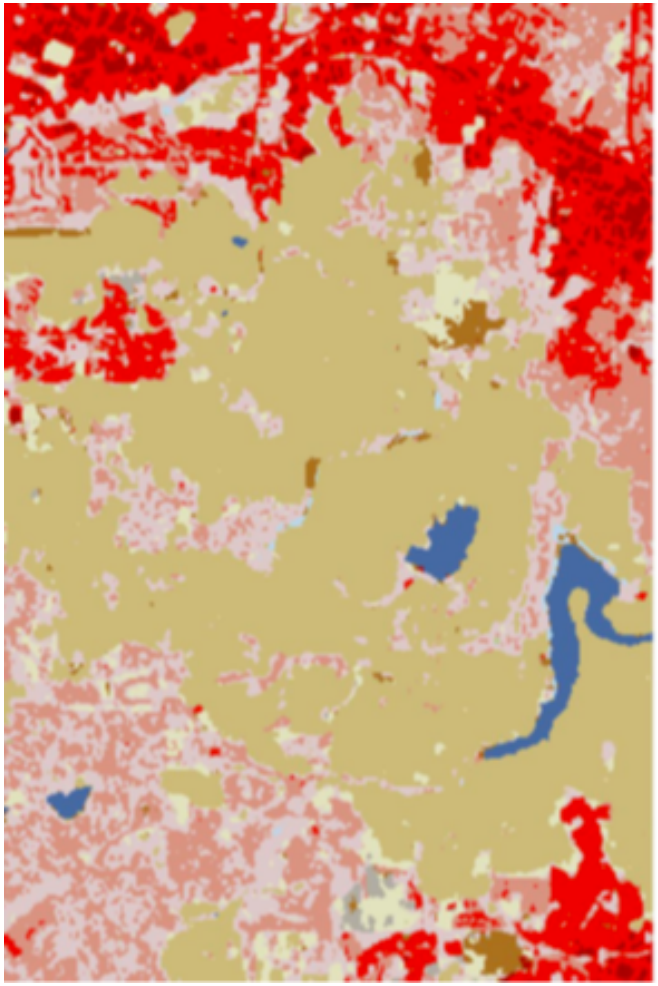
Land Cover Predictions

Original Labels



U-Net Predicted Labels



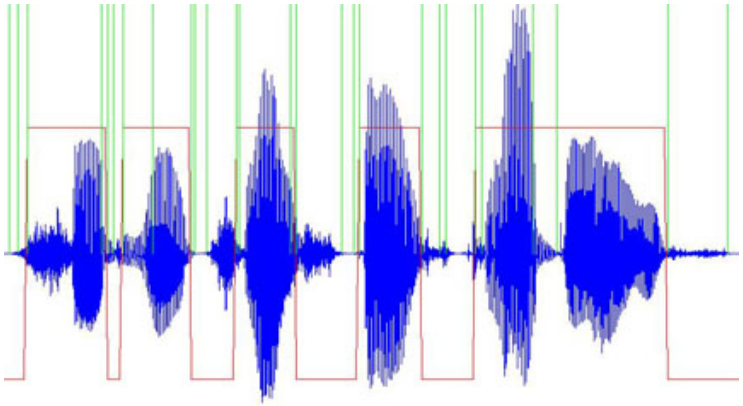
LSTM

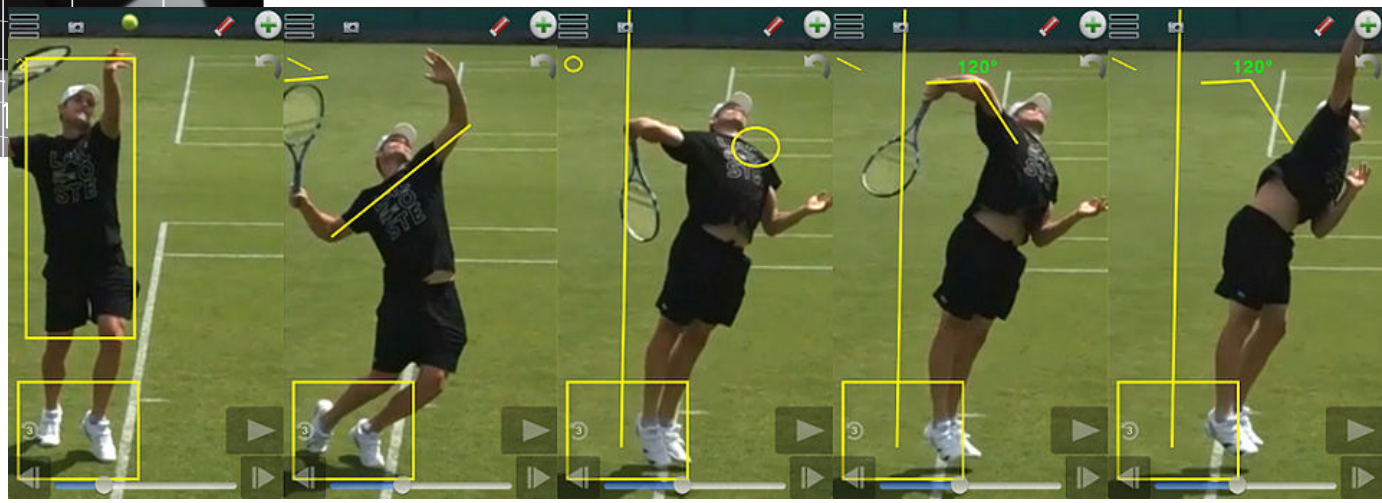
Sequence Learning

- **Problem description**
  - Learning a signal with an ordering or time component

Stock Price

Speech



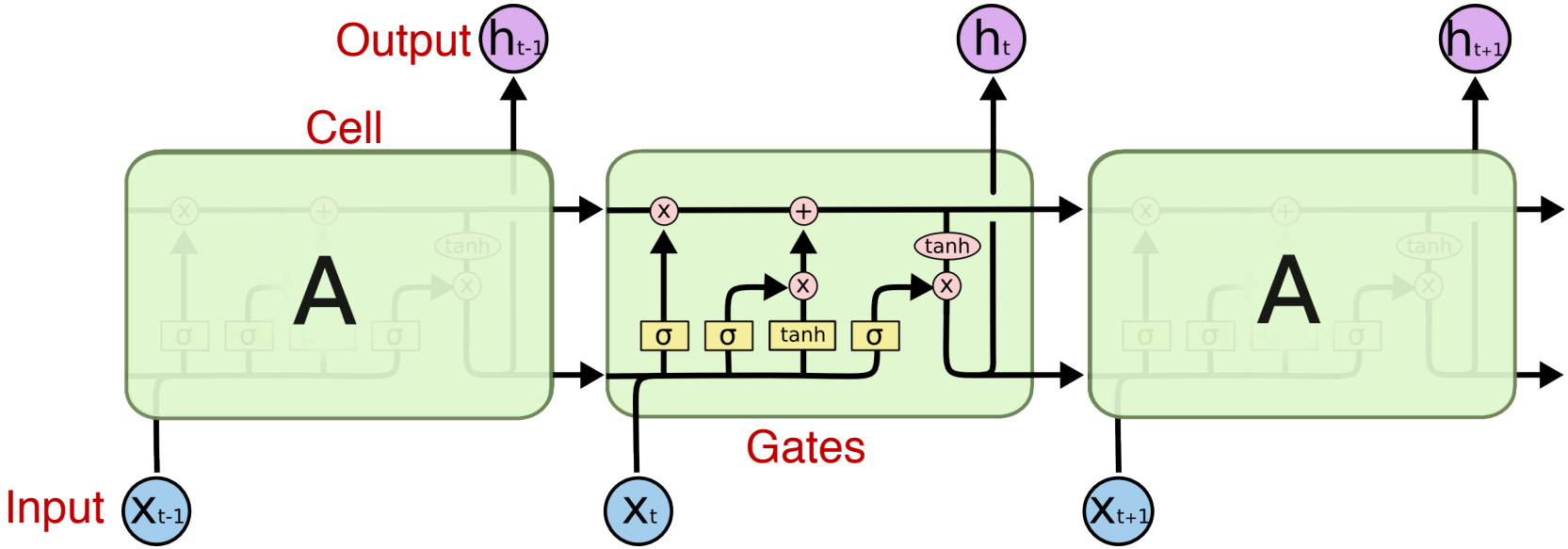


Video

Long Short-Term Memory (LSTM)

- **Recurrent neural network (RNN)**
  - RNNs can model sequences and time-dependent signals
  - RNN architectures have cyclic connections that feed network activations from a previous time step as part of input back to network
    - Allows for temporal contextual information to be stored
    - Predictions at current time step depend on current input and previous predictions
    - Context required must be learned
- **LSTM**
  - Type of RNN
  - Addresses important issues with conventional RNN training

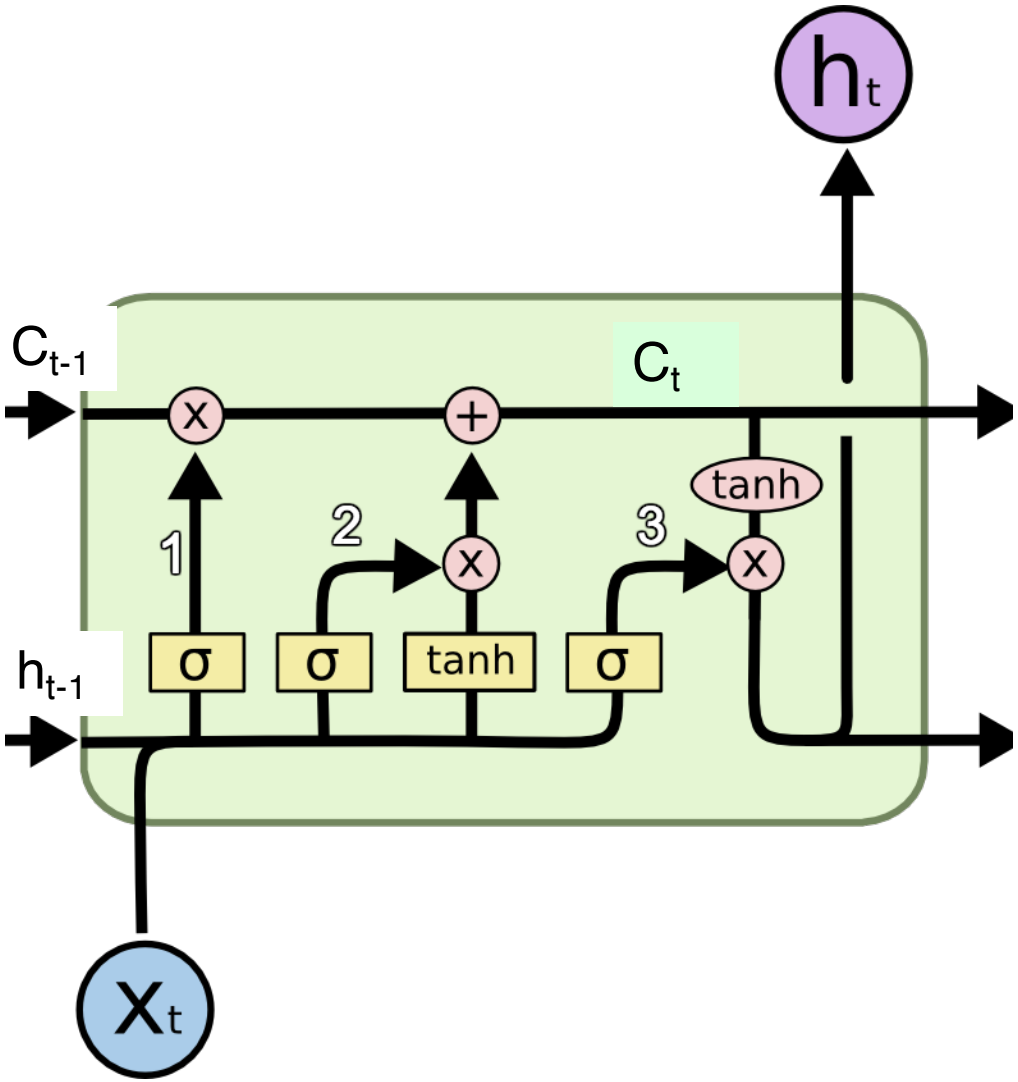
LSTM Architecture



http://colah.github.io/posts/2015-08-Understanding-LSTMs/

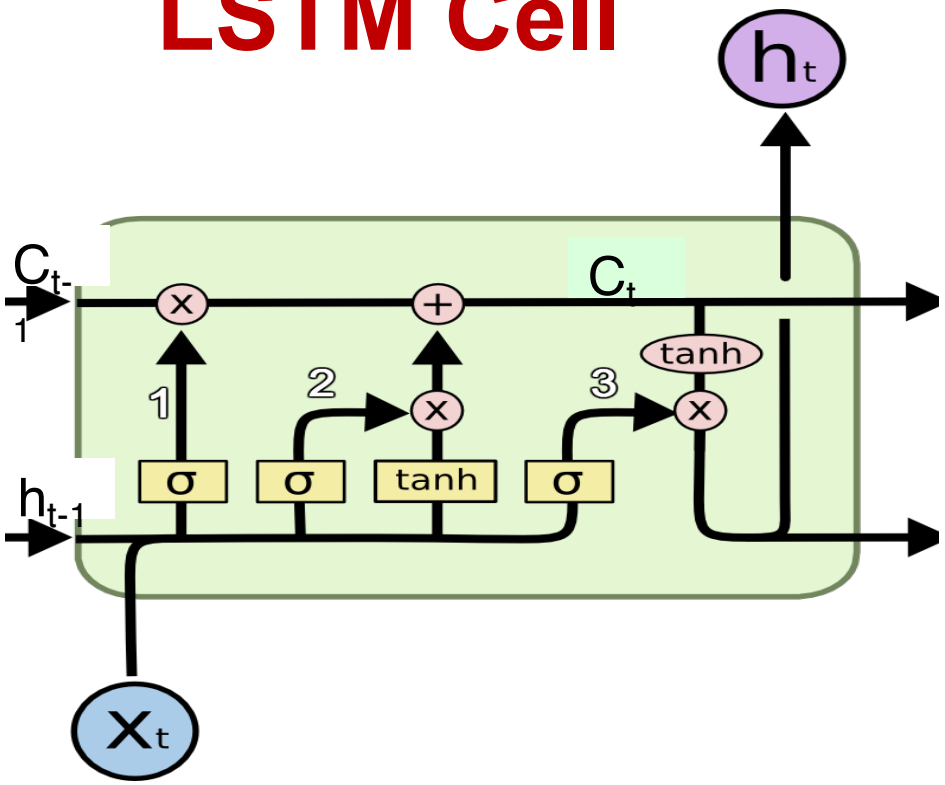
- Info flows through memory blocks called ‘cells’
- Structure of cell allows LSTM to selectively remember/forget pieces of information
- Each cell manipulates memory through ‘gates’

LSTM Cell



- X_t
  - Current input
- C_{t-1}
  - Previous cell state
  - Long-term memory
- h_{t-1}
  - Previous hidden state
  - Output from last cell
  - Working memory
- h_t
  - Current output
- **1: forget gate**
  - Removes info
- **2: input gate**
  - Adds info
- **3: output gate**
  - Selects useful info as output

LSTM Cell



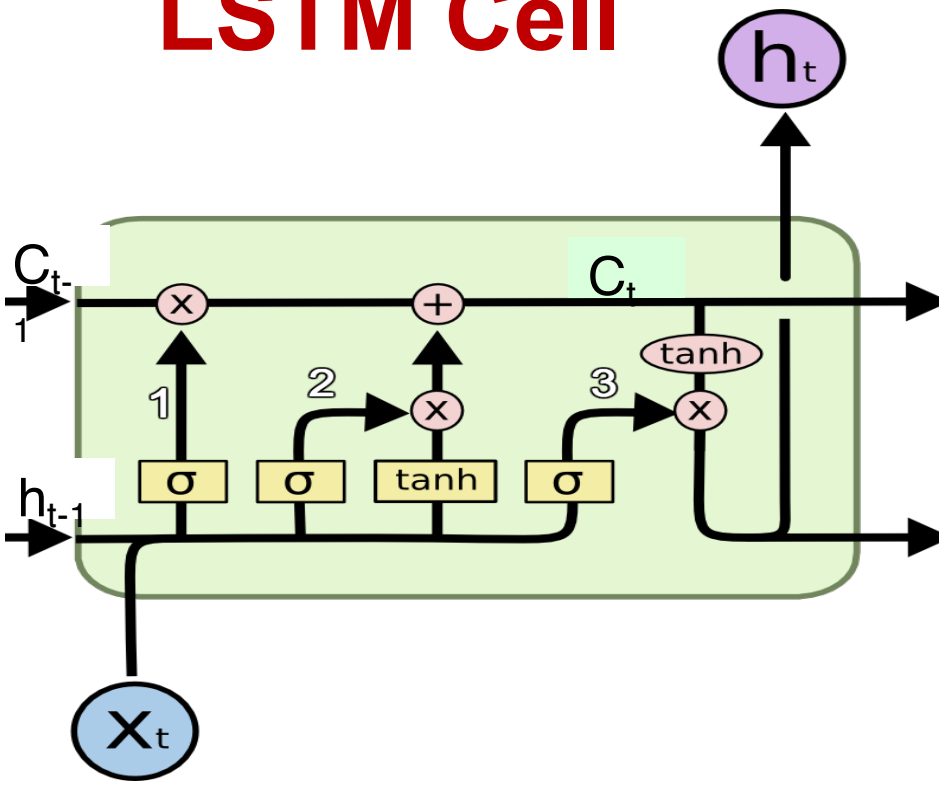
- **1: forget gate**
  - Forgetting mechanism
  - When new input comes in, determines what information to remove from cell state (long-term memory)
  - Input is multiplied by learned weights, then filter is applied.
  - Resulting vector is multiplied by cell state.

Example

Steve is my co-worker => subject=Steve, gender=Male

His wife, Lauren, is a chef. => subject=~~Steve~~ Lauren, gender=~~Male~~ Female

LSTM Cell



- **2: input gate**
  - Saving mechanism
  - When new input comes in, determines what information to add to long-term memory
  - Input is multiplied by learned weights, then filter is applied.
  - Resulting vector is multiplied with new candidate inputs.
  - Add new info to long-term memory

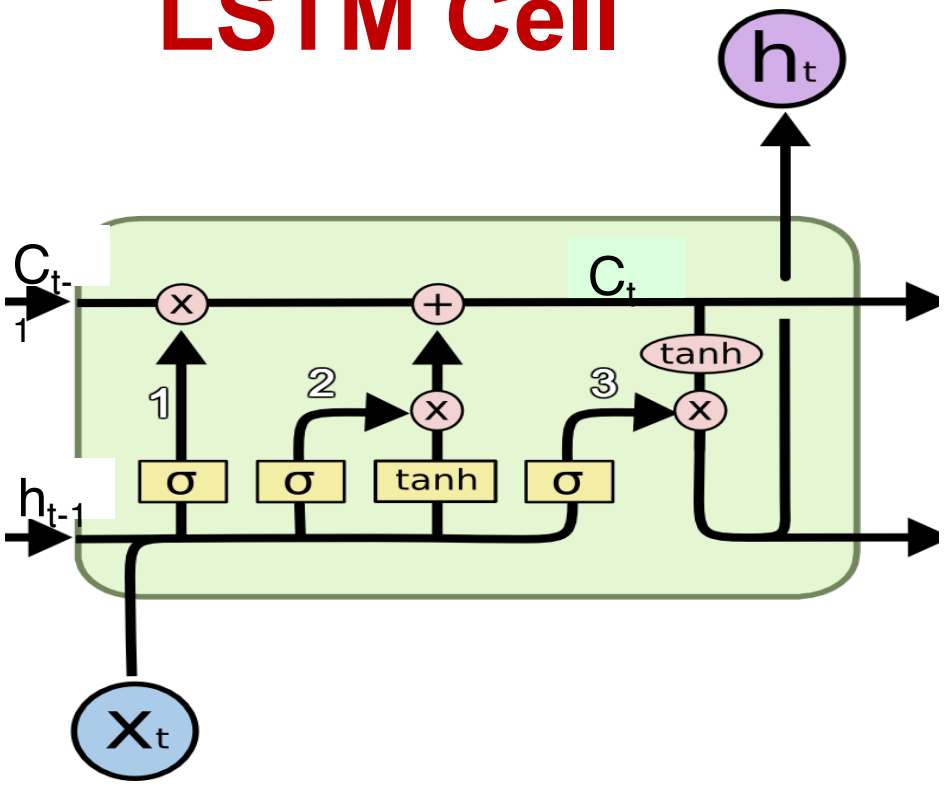
Example

Steve told me last week that he went to culinary school.

⇒ To add: “went to culinary school”

⇒ Not important: “told me last week”

LSTM Cell



- **3: output gate**
  - Determines what information from long-term memory is immediately useful
  - Input is multiplied by learned weights, then filter is applied
  - Resulting vector is multiplied by cell state
  - This is output of cell (also hidden state to next cell)
  - Instead of using full long-term memory all the time, learn which parts to focus on at each step

Example

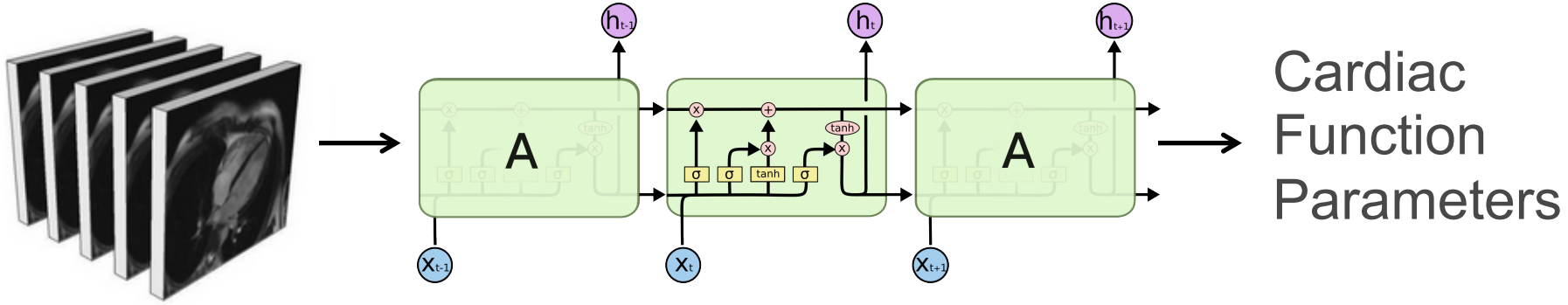
I always knew that they both had a passion for _____

⇒ cooking

LSTM for Performance Prediction

- **Predict job status of computer processes**
  - To maximize resource allocation
- **Complex and distributed workflows**
  - Combine several executables
  - Require various hardware and software support
- **Characterize workload**
  - Predict whether job will fail
  - Move job to different resources as needed for efficient processing

LSTM for Cardiac Image Analysis



- Take into account dynamic nature of cardiac cycle
- Motion of heart can indicate local malfunctions

LSTM Applications

- Speech recognition
- Machine translation
- Language modeling
- Speech synthesis
- Handwriting recognition
- Text generation
- Video analysis
- Protein structure prediction
- Stock price prediction

References

- **U-Net**
  - Original paper:
    - https://arxiv.org/abs/1505.04597
  - U-Net & Keras
    - https://spark-in.me/post/unet-adventures-part-one-getting-acquainted-with-unet
  - U-Net for medical image segmentation
    - https://towardsdatascience.com/medical-image-segmentation-part-1-unet-convolutional-networks-with-interactive-code-70f0f17f46c6
  - Satellite image analysis use case:
    - https://ieeexplore.ieee.org/abstract/document/8621883

References

- **LSTM**
  - Original paper
    - https://www.mitpressjournals.org/doi/abs/10.1162/neco.1997.9.8.1735
  - Understanding LSTM Networks
    - http://colah.github.io/posts/2015-08-Understanding-LSTMs/
  - Introduction to LSTM
    - https://www.analyticsvidhya.com/blog/2017/12/fundamentals-of-deep-learning-introduction-to-lstm/
  - Understanding LSTM
    - https://towardsdatascience.com/understanding-lstm-and-its-quick-implementation-in-keras-for-sentiment-analysis-af410fd85b47

Deep Learning Topics

- **Deep Learning Overview**
  - Neural network & deep learning overview
  - MNIST tutorial
- **CNN Transfer Learning with Keras**
  - Pre-trained CNN to speed up CNN training
  - Feature extraction & fine tuning
- **FasterCNN**
  - Object detection
- **Unet**
  - Segmentation
- **LSTM**
  - Sequence & temporal learning

Questions?