2018 Summer Institute
Deep Learning

SDSC SAN DIEGO SUPERCOMPUTER CENTER

UC San Diego

U-Net and LSTM

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U-Net

Image Segmentation

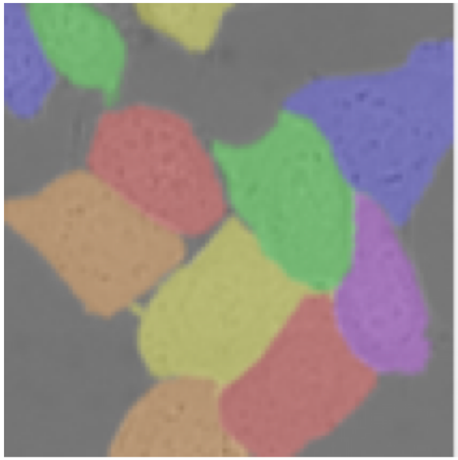
- **Dividing image into multiple salient image regions**
  - Assign label to every pixel in image
  - Pixels with same label are similar

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

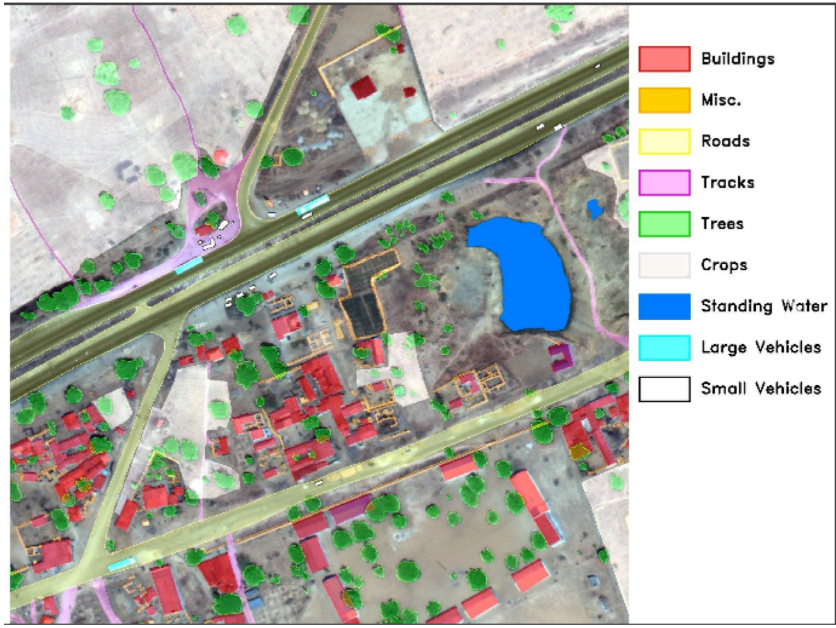
U-Net

- **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

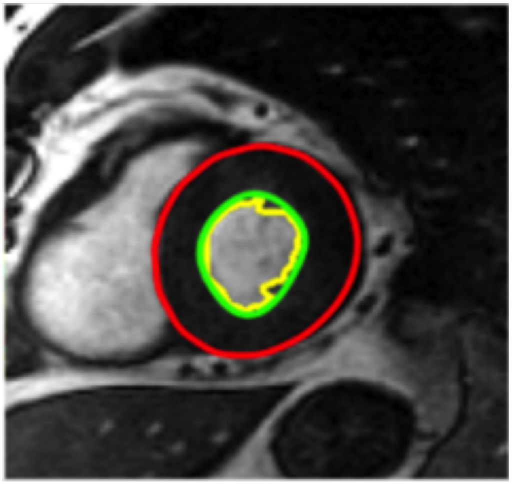


Biomedical Segmentation



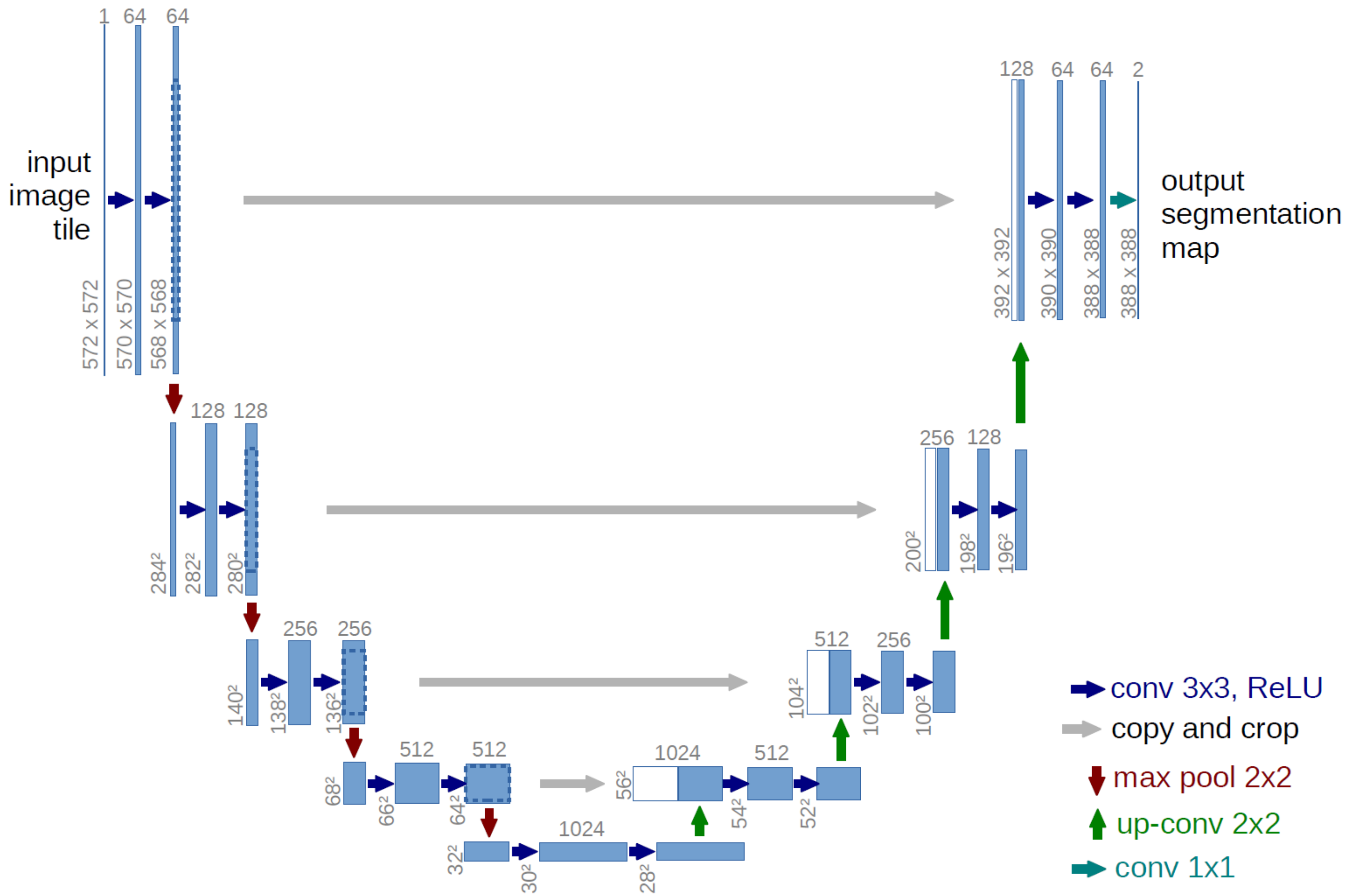
Satellite Image Processing

Object Detection



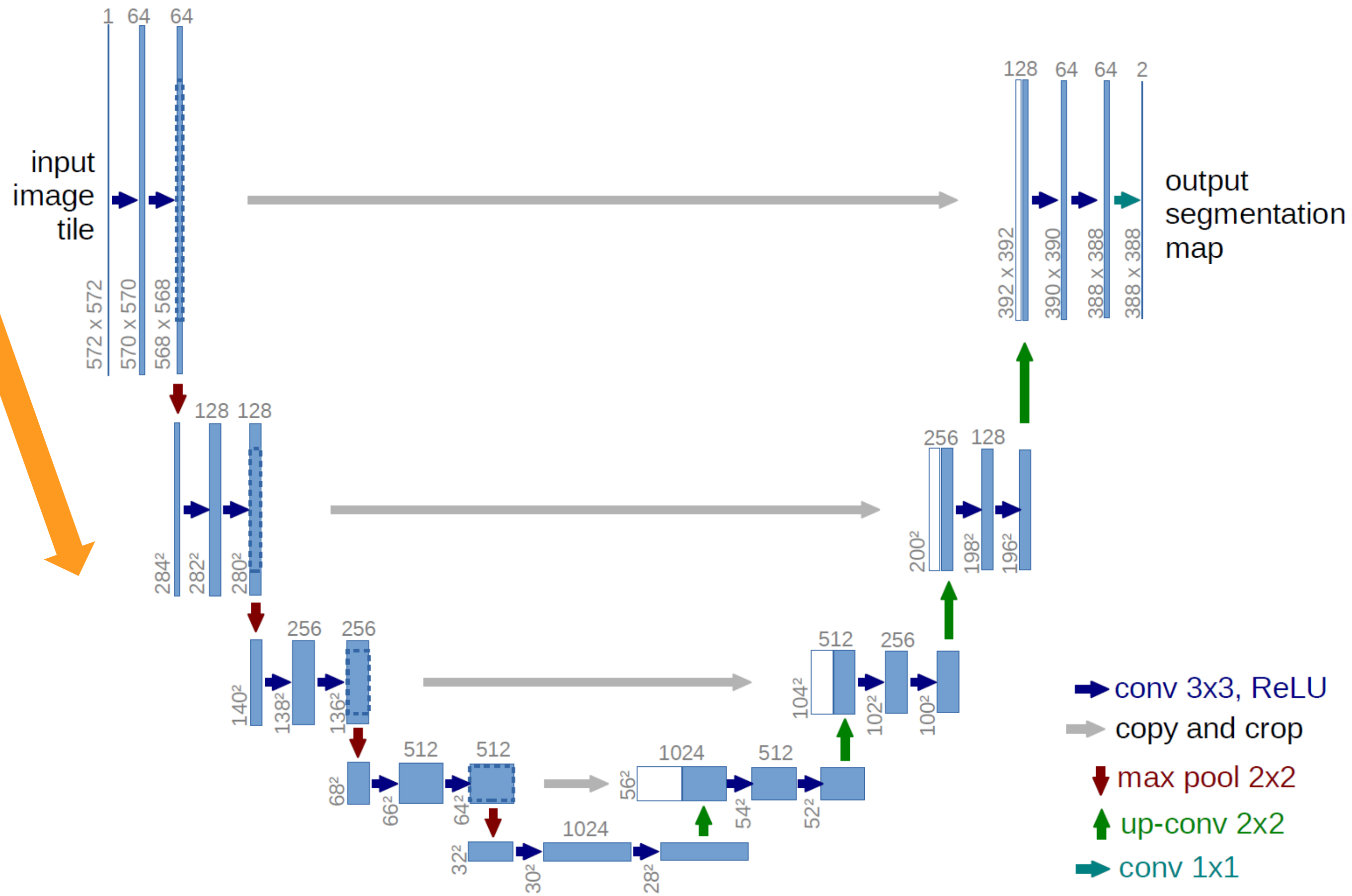
Medical Image Analysis

U-Net Architecture



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

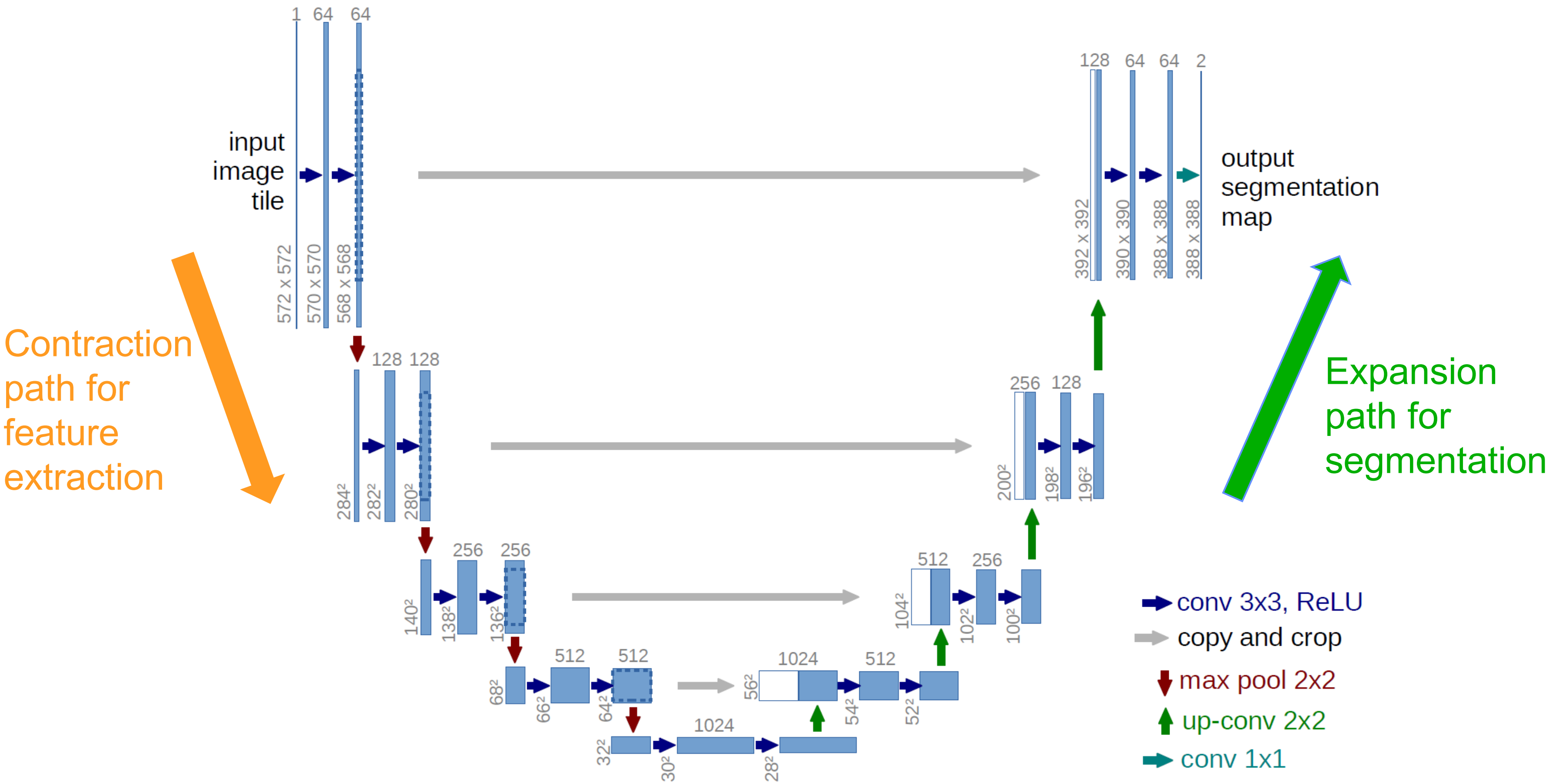
U-Net Architecture



Contraction path for feature extraction

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

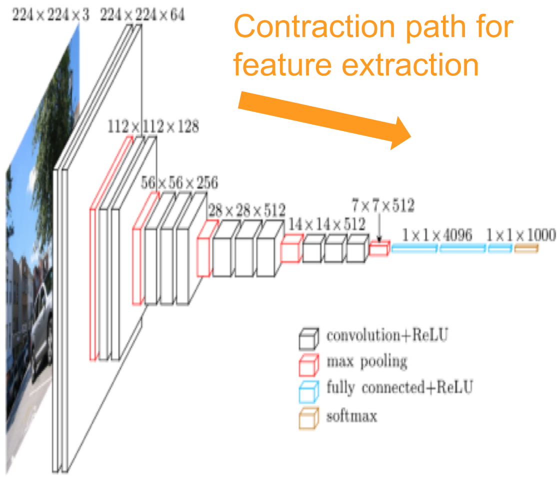
U-Net Architecture



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

U-Net Architecture

VGG16 CNN Architecture

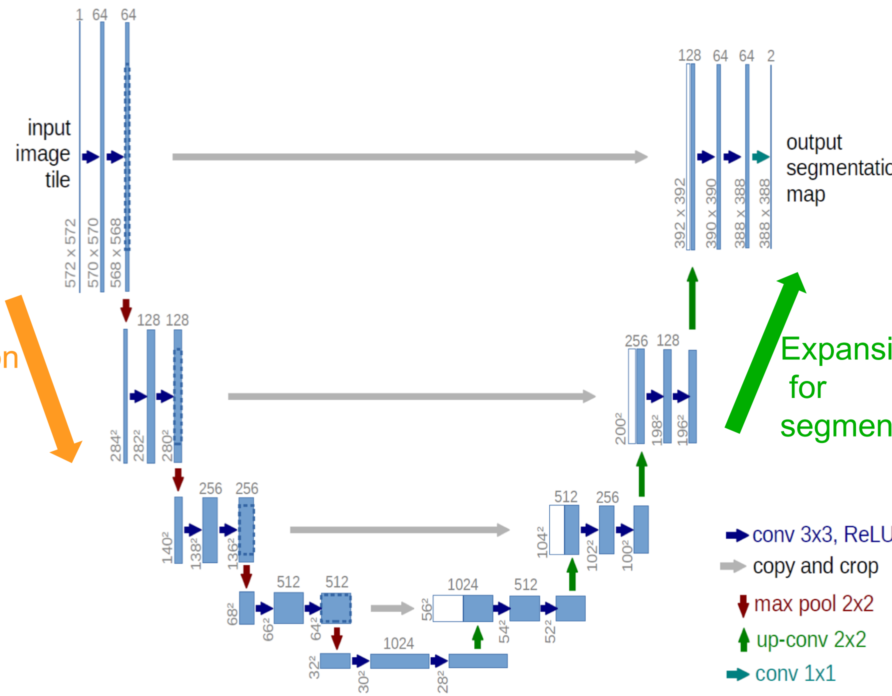


Contraction path for feature extraction

Classification

U-Net Architecture

Contraction path for feature extraction



Expansion path for segmentation

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

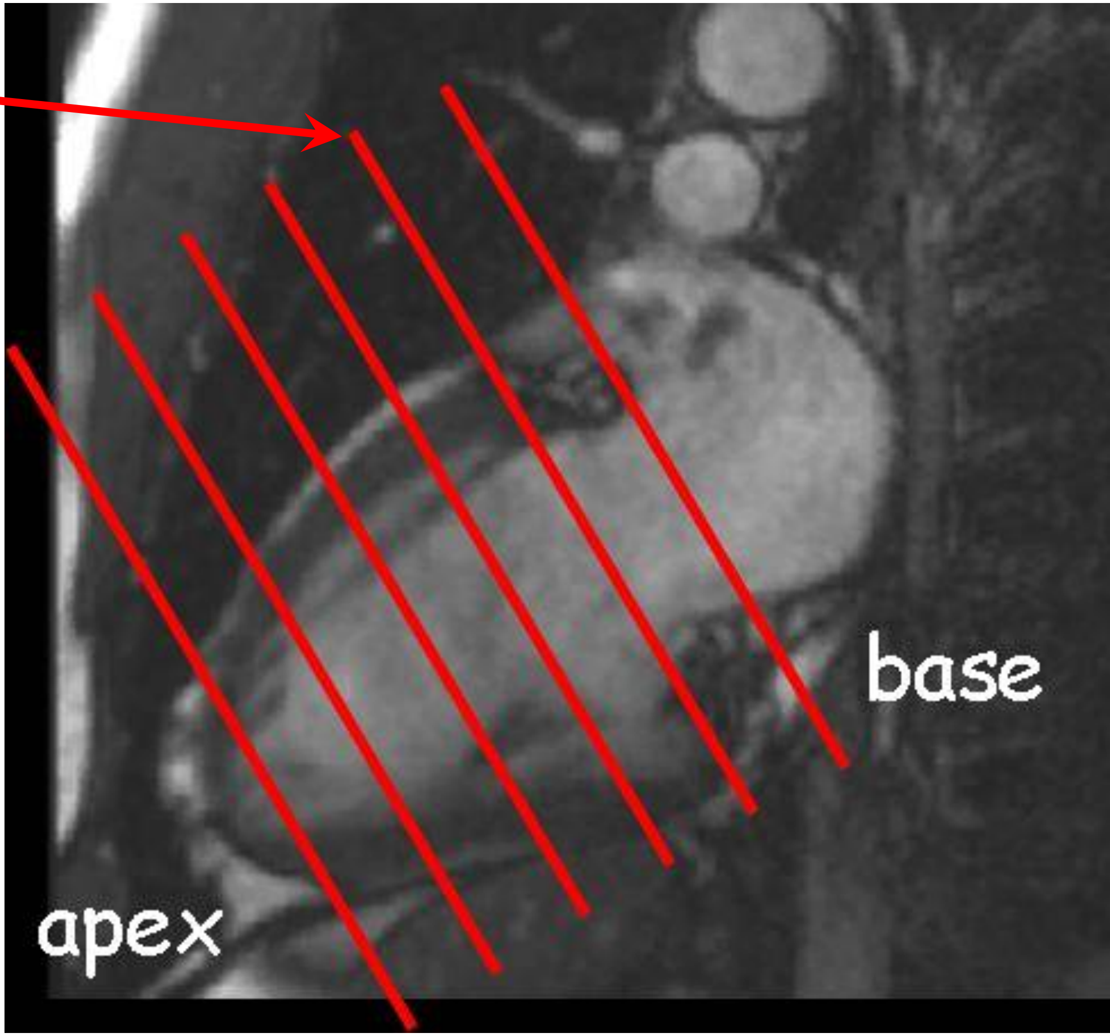
https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/

U-Net Case Study

- **Cardiac image analysis**
- **Goal**
  - Aid in non-invasive detection of cardiac disease
- **Motivation**
  - Cardiac imaging allows visualization of heart structure and functionality non-invasively
  - But process of analyzing cardiac images is time-consuming and labor-intensive
- **Approach**
  - Apply deep/machine learning to provide faster and more consistent analysis results

Cardiac Images

- **Slices**
  - At different locations to cover heart
  - Each slice acquired on single breath hold
- **Frames**
  - 2D images of heart during heartbeat
  - MRI: 10-30 frames per slice

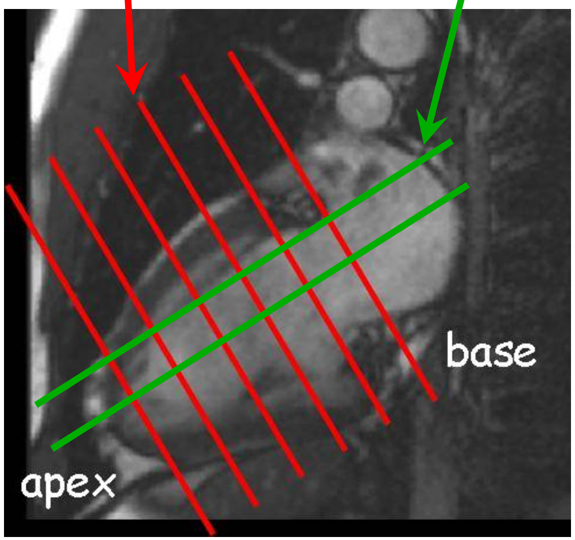


http://radiology.cornfeld.org/CMR/planes.php

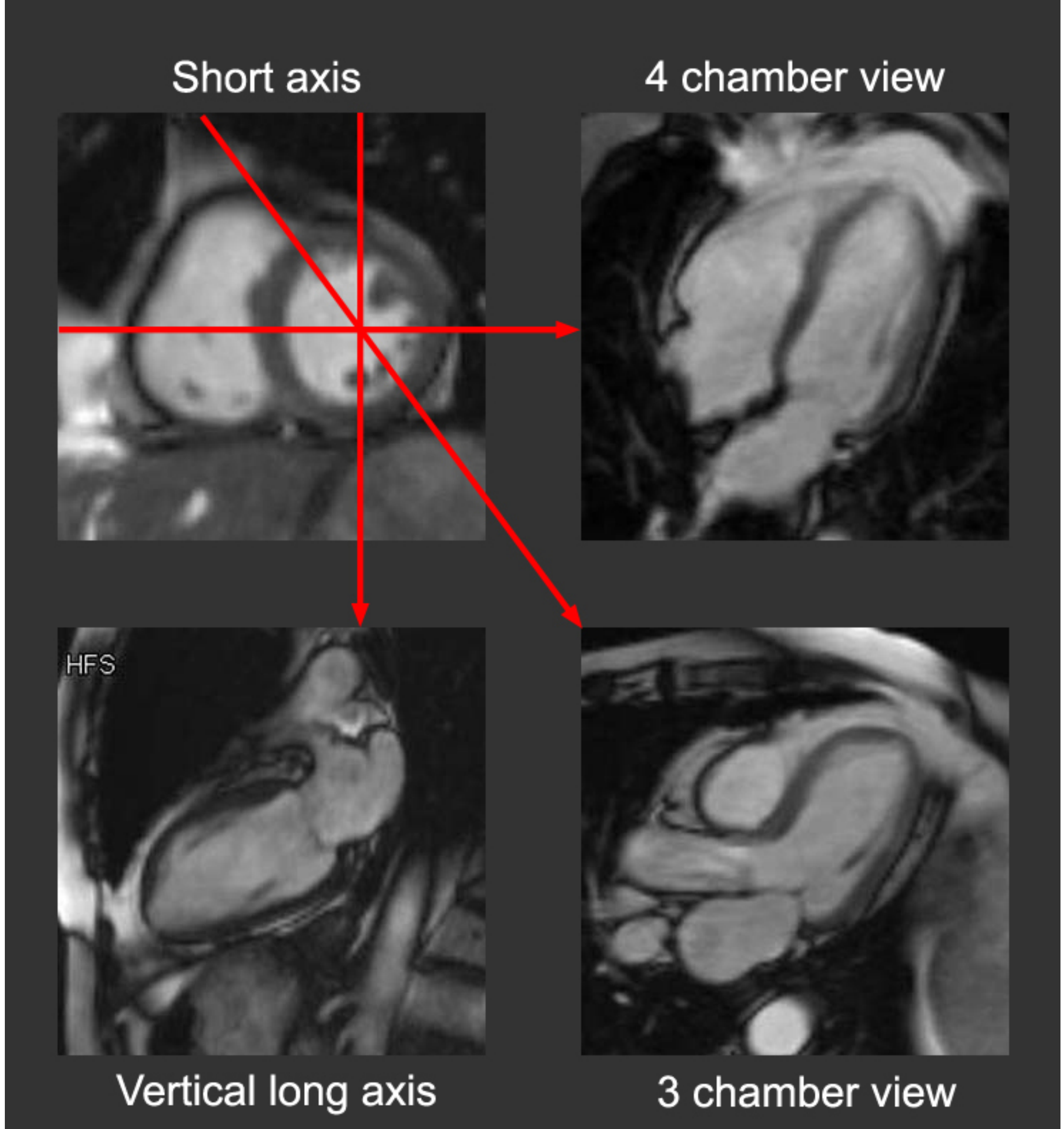
Different Views of Heart

short axis

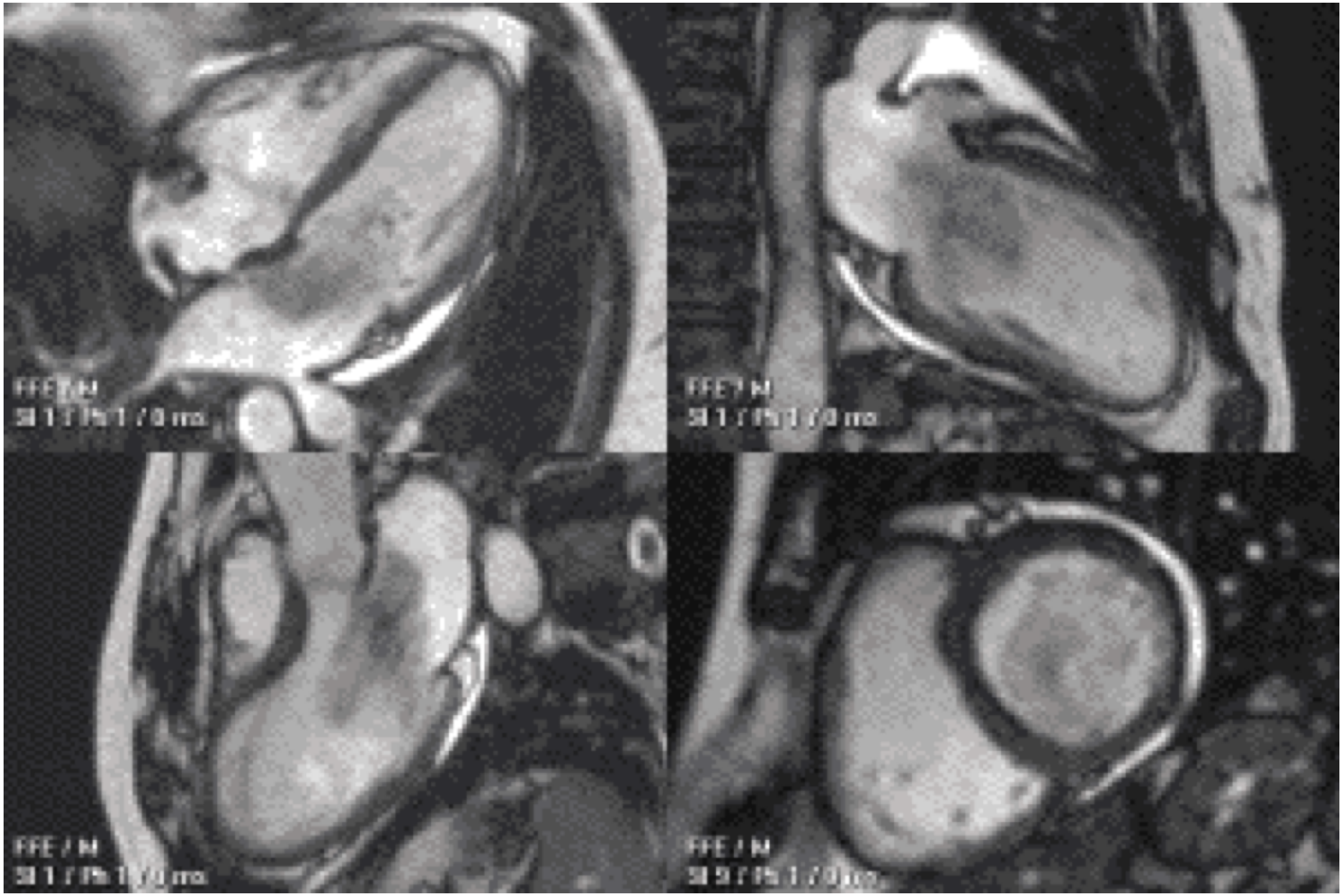
long axis



https://www.med-ed.virginia.edu/courses/rad/cardiacmr/Anatomy/Views.html



Cardiac Cine

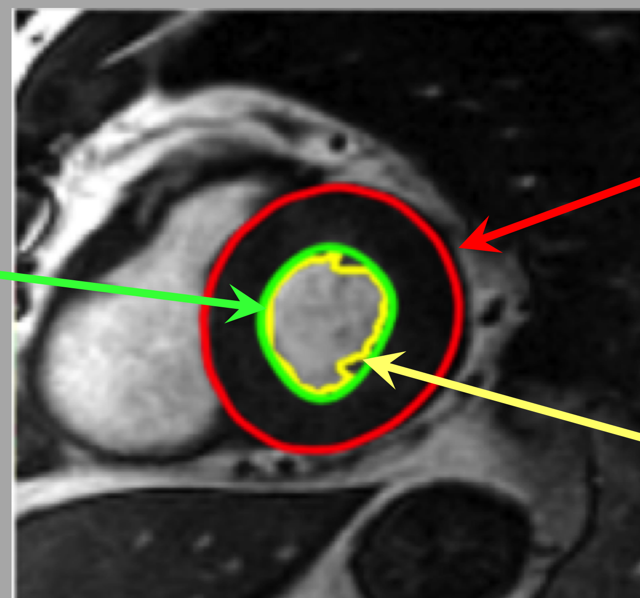


https://en.wikipedia.org/wiki/Cardiac_magnetic_resonance_imaging

LV Segmentation

- **LV contours**

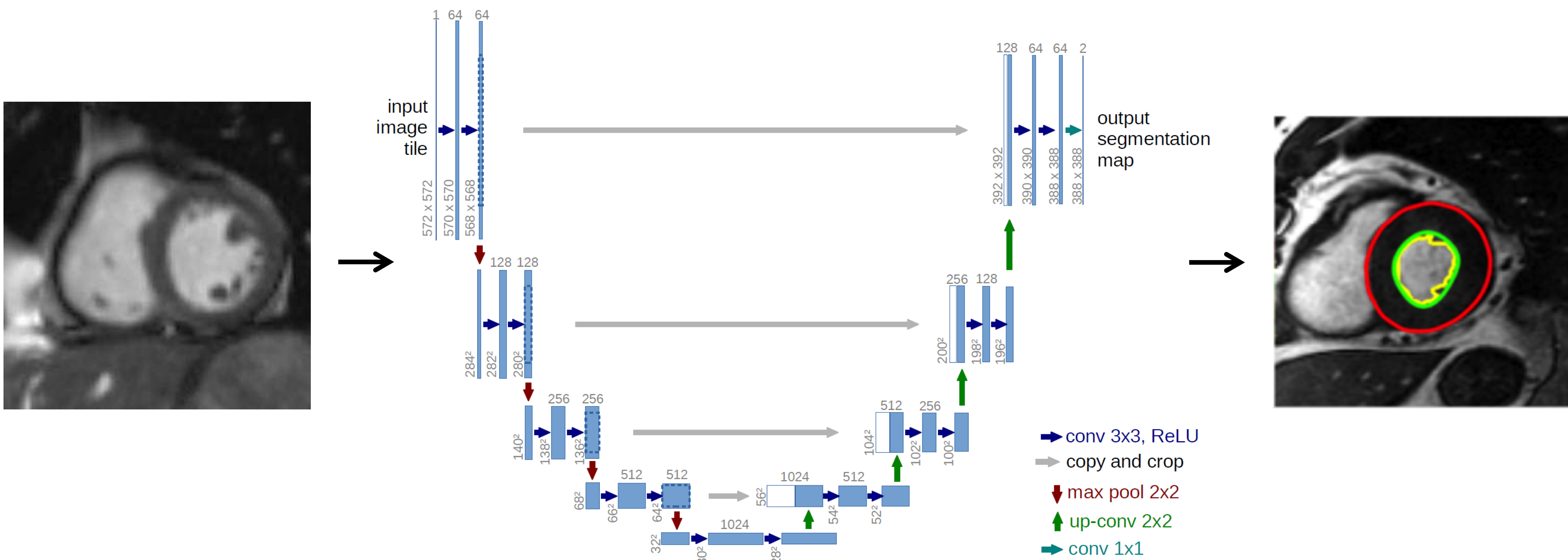
http://smial.sri.utoronto.ca/LV_Challenge/Home.html



- **Current approach:**
  - Predict endocardial contour

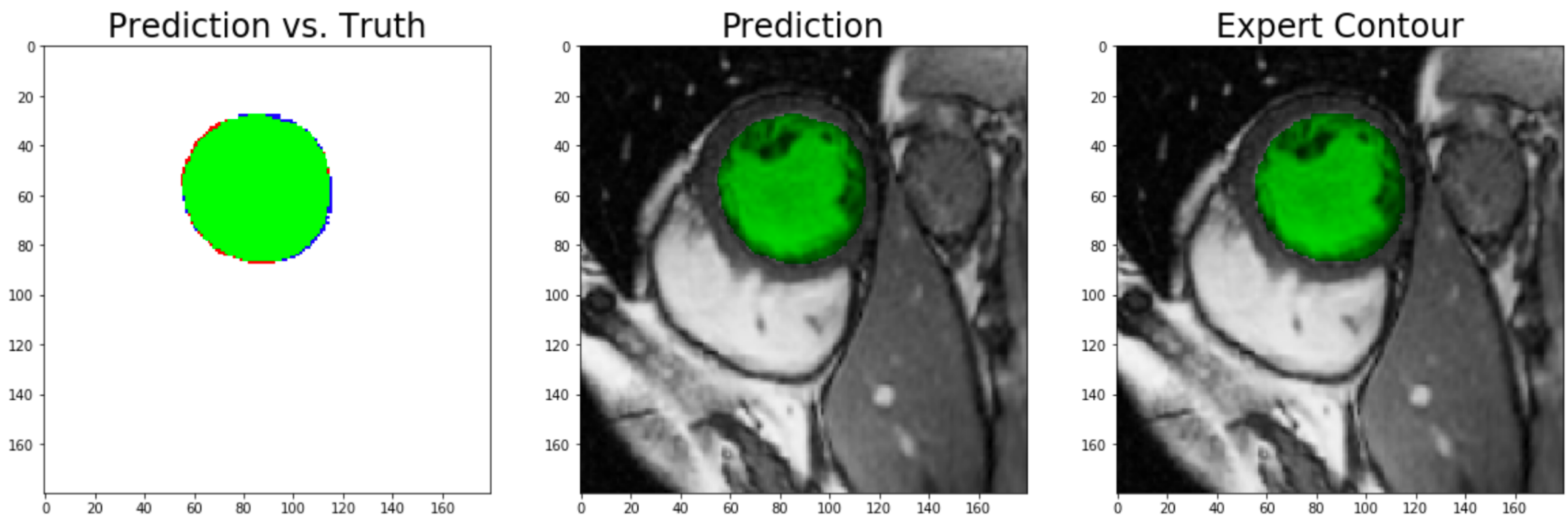
Medical Image Analysis

- **Segmentation**



LV Segmentation on Test Image

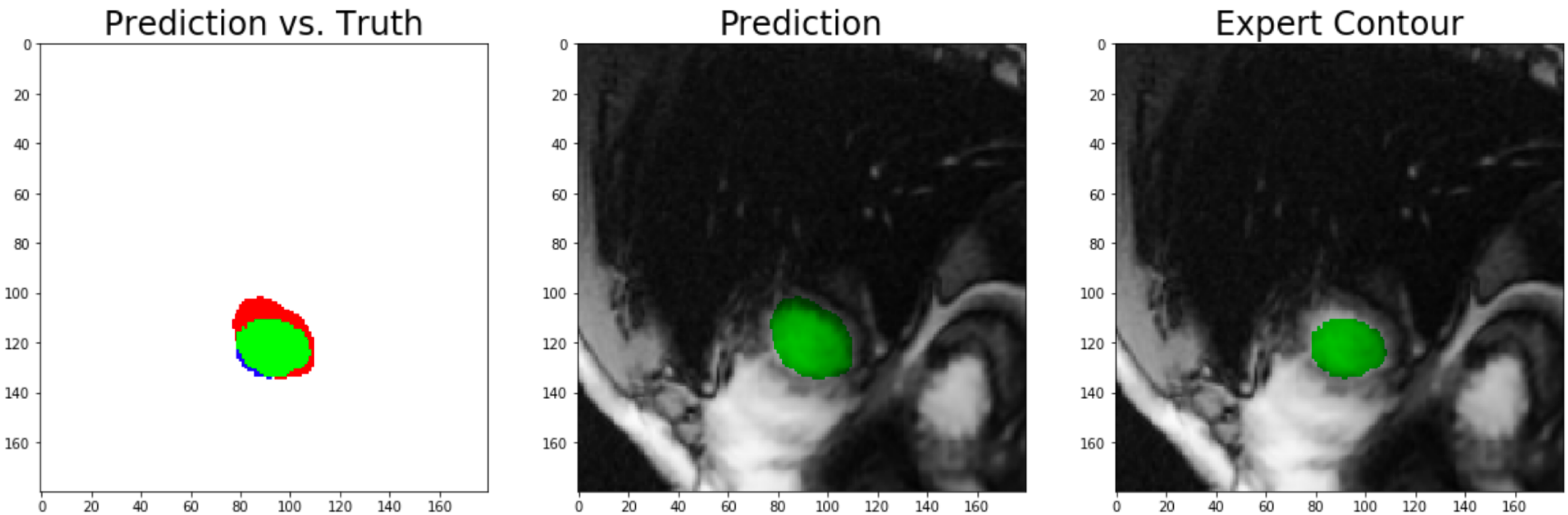
```
PatientsName: ^SC-N-9 SeriesNumber: 302 InstanceNumber 80
dice coefficient: 97.6047904192
```



True Positive : green   True Negative: white
False Positive: red   False Negative: blue

LV Segmentation on Test Image

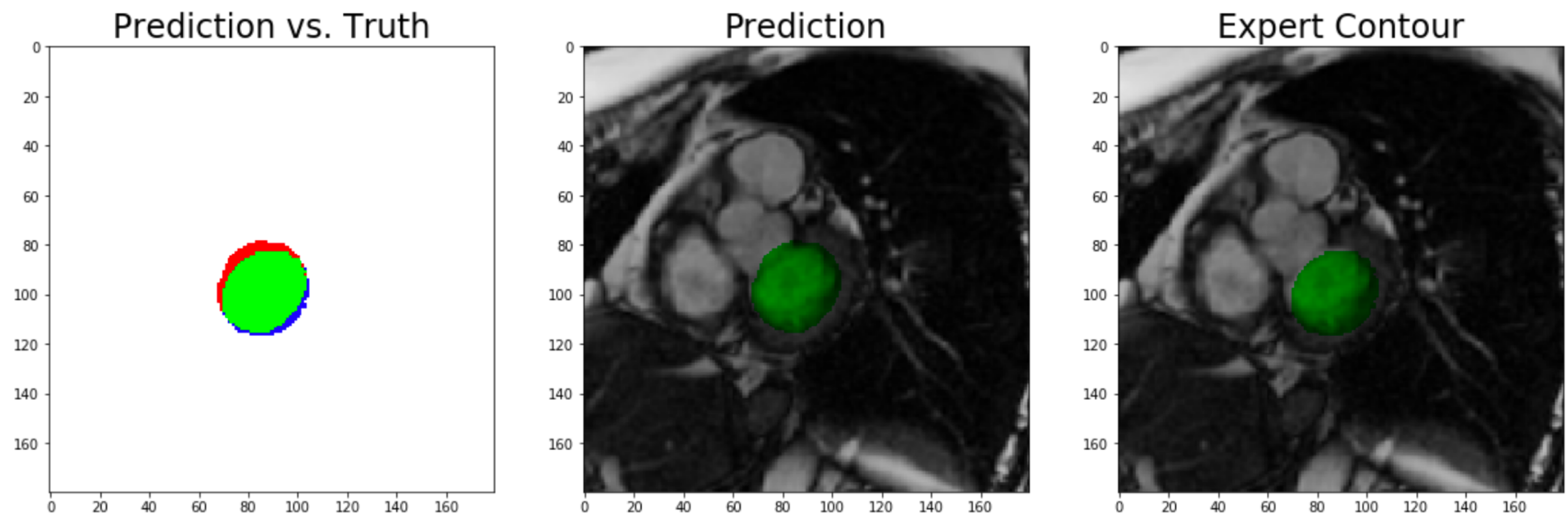
```
PatientsName: ^SC-HF-NI-14 SeriesNumber: 303 InstanceNumber 216
dice coefficient: 77.4945375091
```



True Positive : green
True Negative: white
False Positive: red
False Negative: blue

LV Segmentation on Test Image

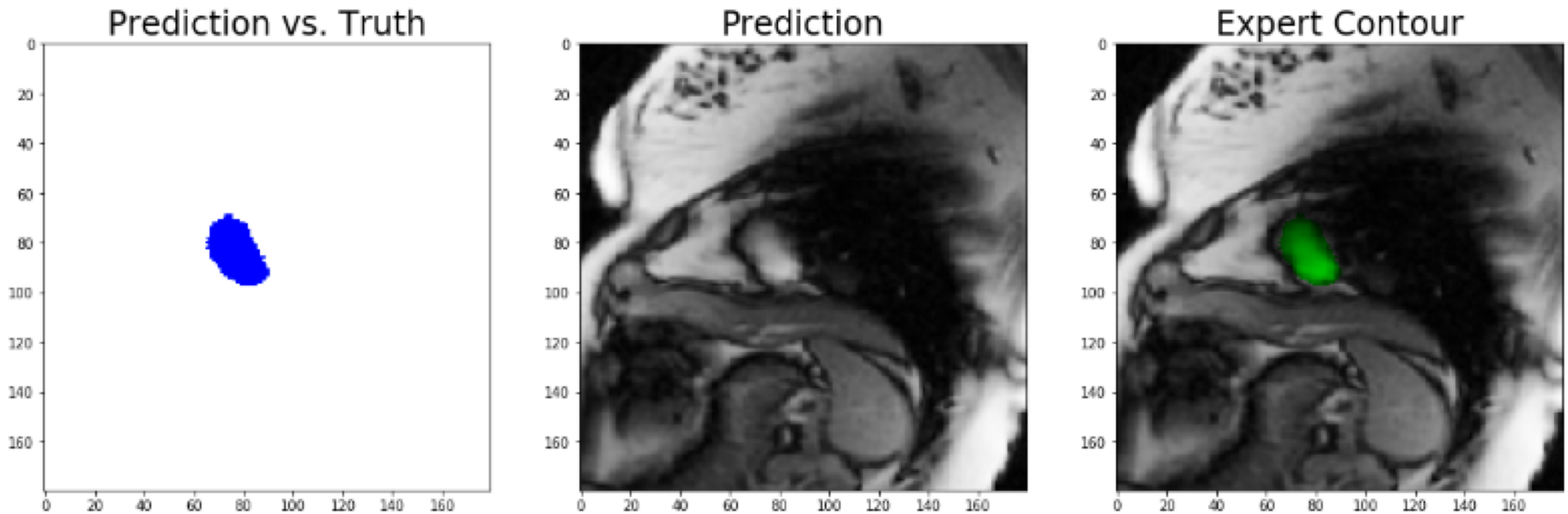
```
PatientsName: ^SC-HYP-11 SeriesNumber: 300 InstanceNumber 80
dice coefficient: 87.8665318504
```



True Positive : green
False Positive: red
True Negative: white
False Negative: blue

LV Segmentation on Test Image

```
PatientsName: ^SC-HF-NI-13 SeriesNumber: 400 InstanceNumber 208
dice coefficient: 0.0
```



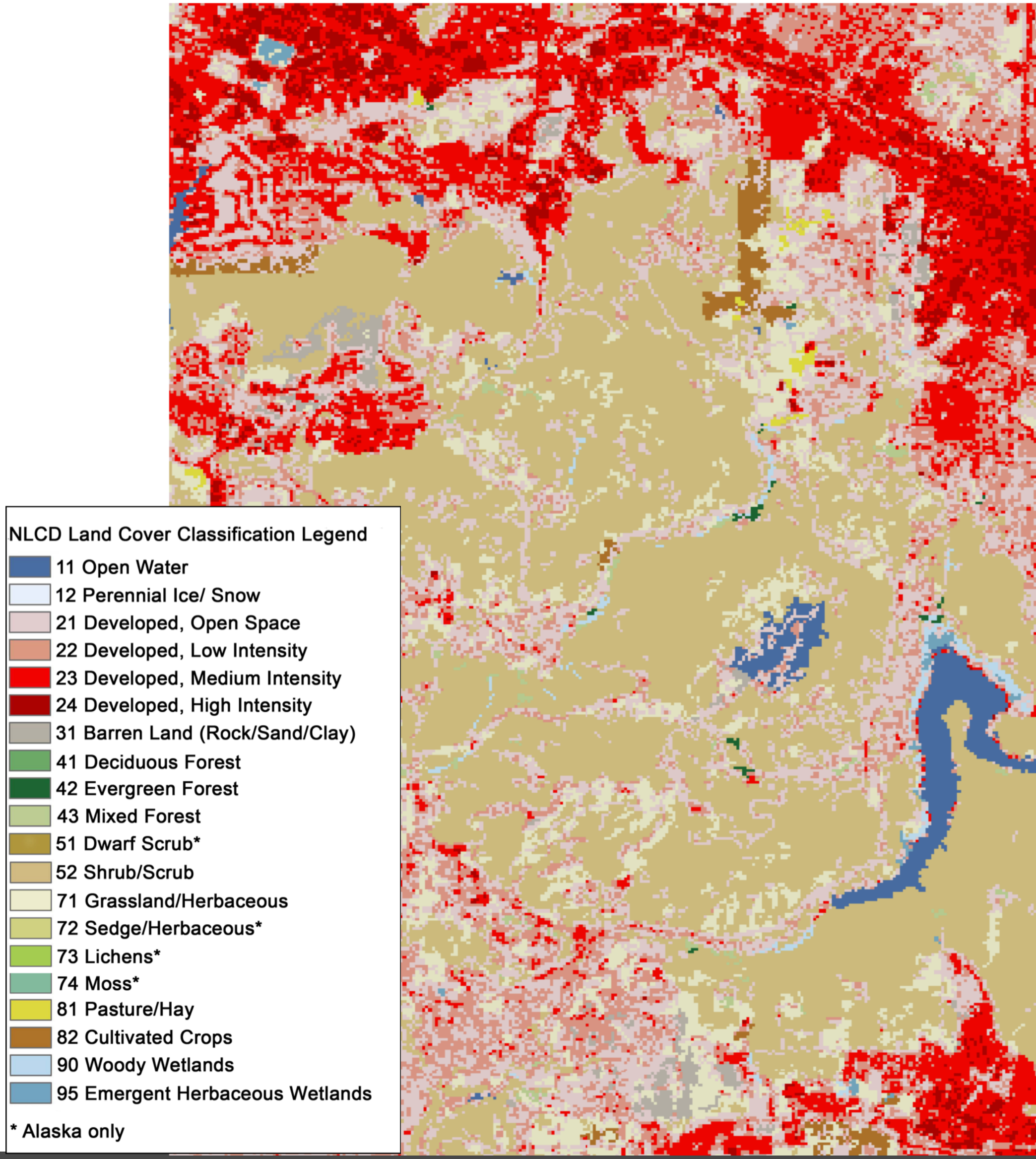
True Positive : green   True Negative: white
False Positive: red   False Negative: blue

Another U-Net Use Case

Satellite Image Analysis

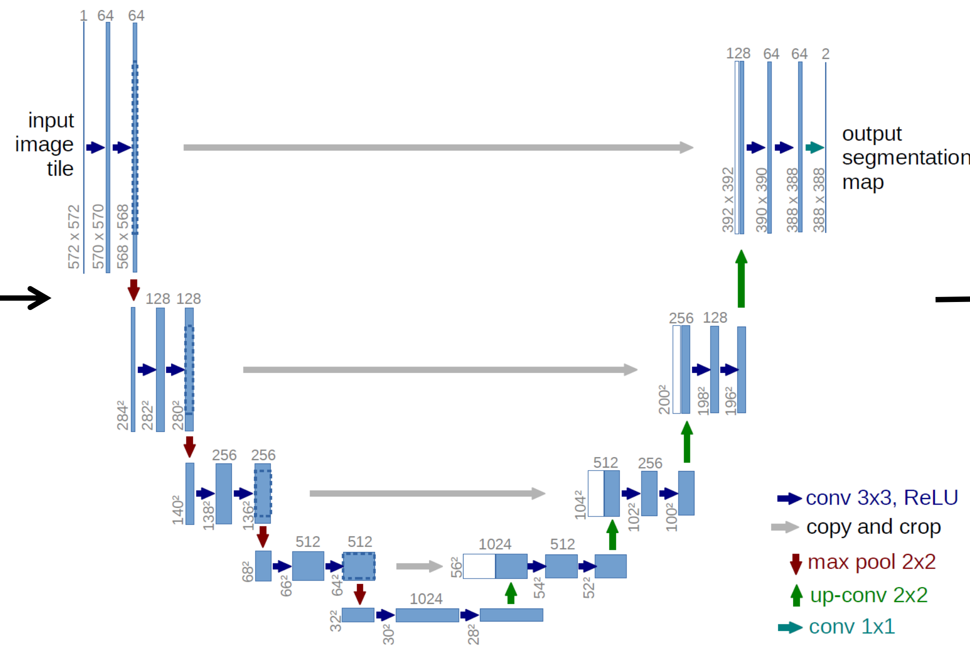
- **Goal**
  - Generate land cover maps from satellite imagery
- **Motivation**
  - Land data products are critical for many applications
  - Current land data products are released every few years
  - Want to generate land data products at scale, as needed, and based on up-to-date data
- **Approach**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

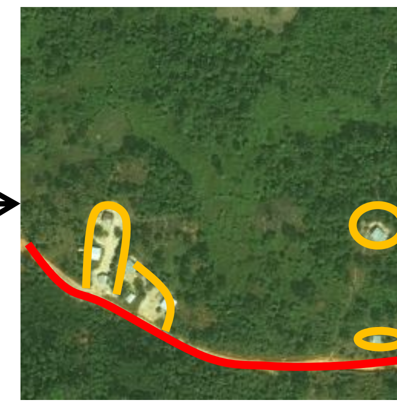
Land Cover Map Example



Deep Learning

U-Net

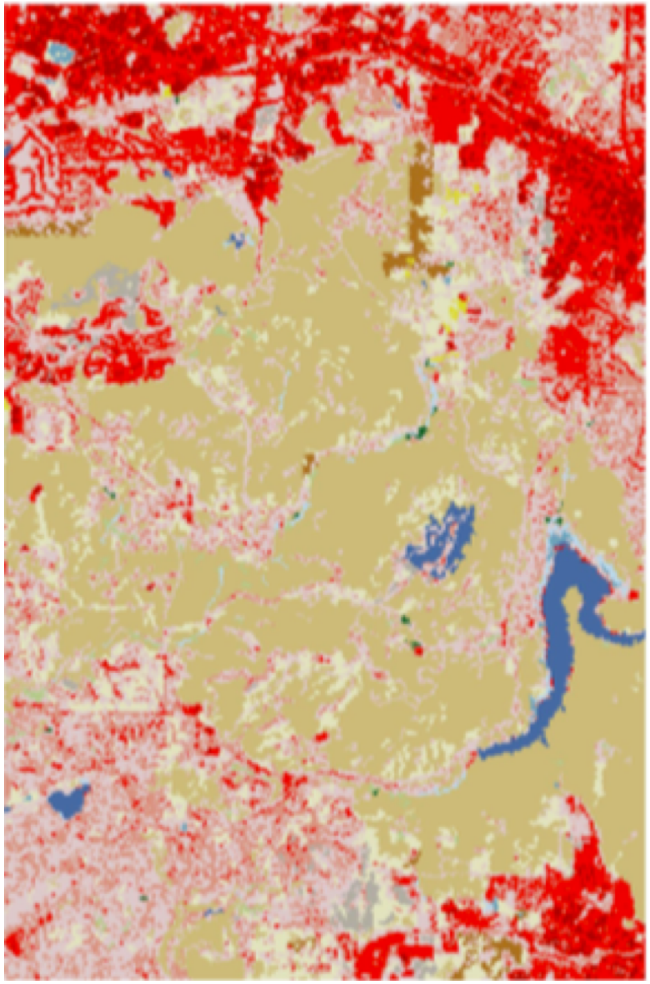




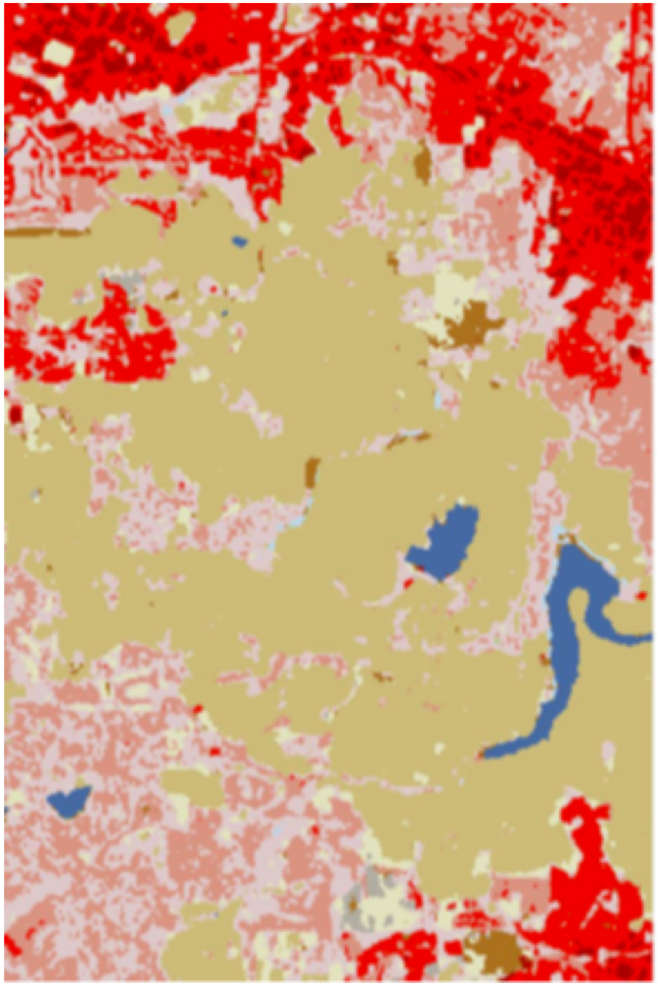
https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/

Land Cover Predictions

Original Labels



U-Net Predicted Labels



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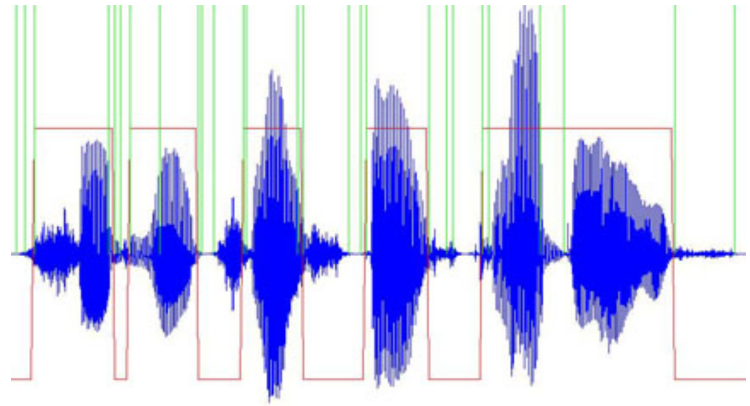
LSTM

Sequence Learning

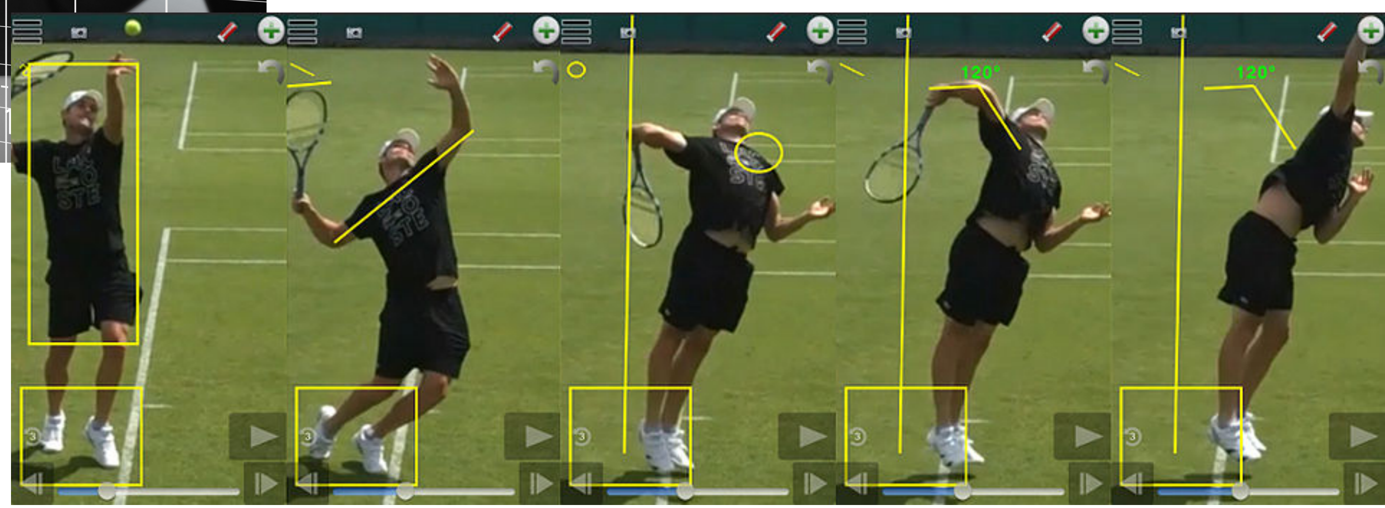
- **Problem description**
  - Learning a signal with an ordering or time component

Stock Price

Speech



Video



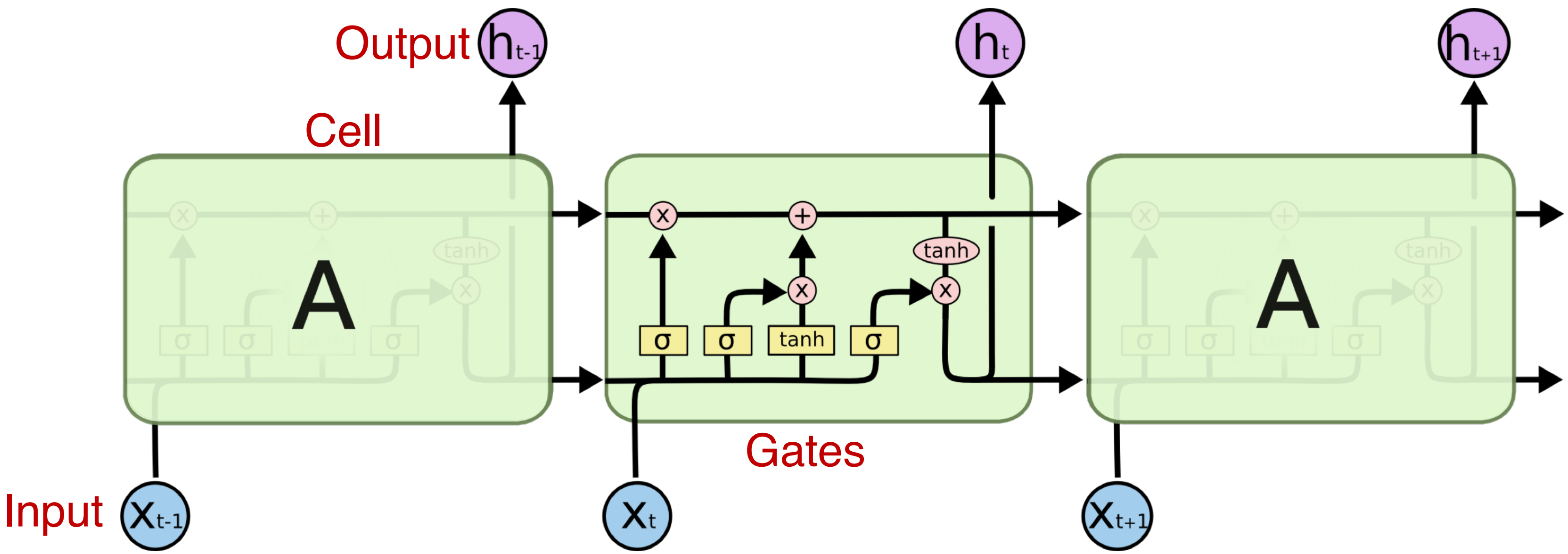
Long Short-Term Memory (LSTM)

- **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 Applications

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

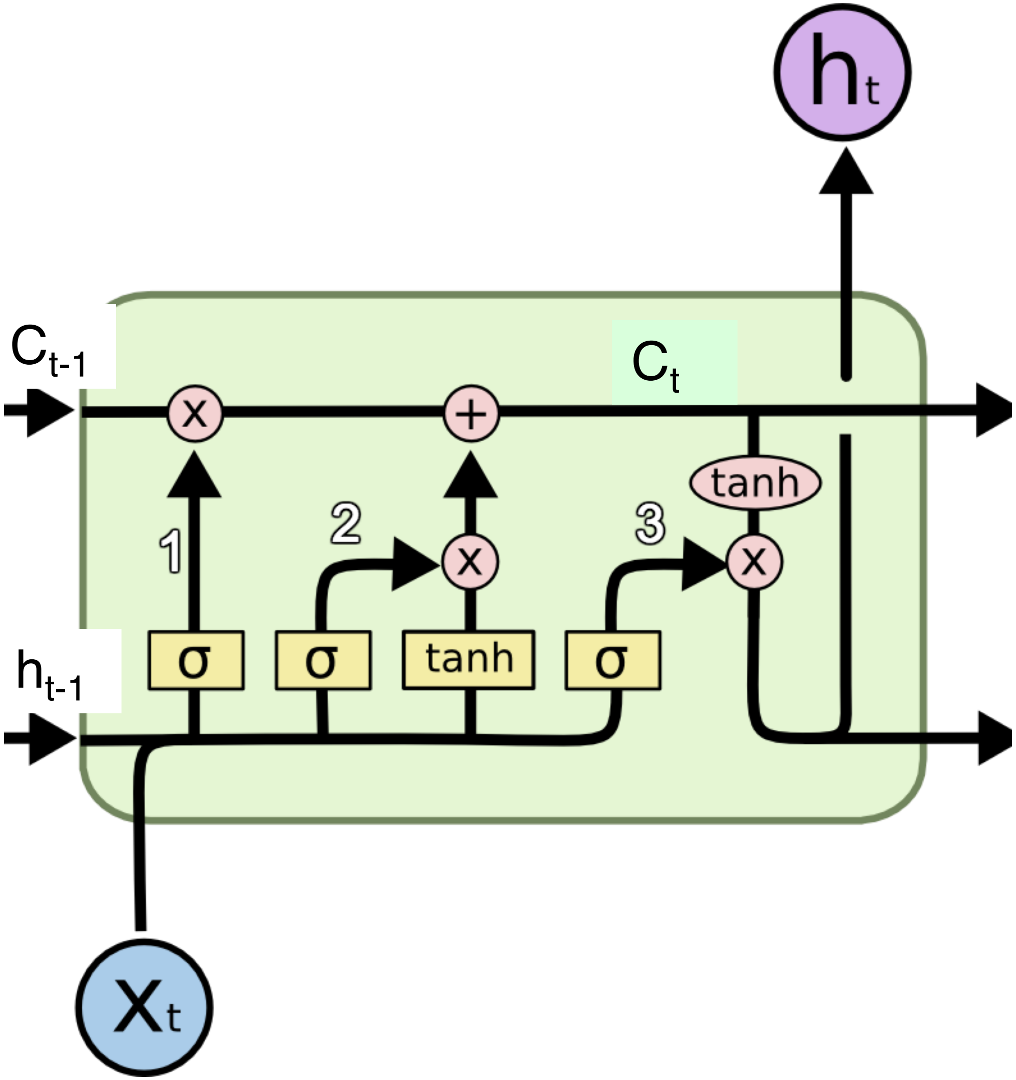
LSTM Architecture



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



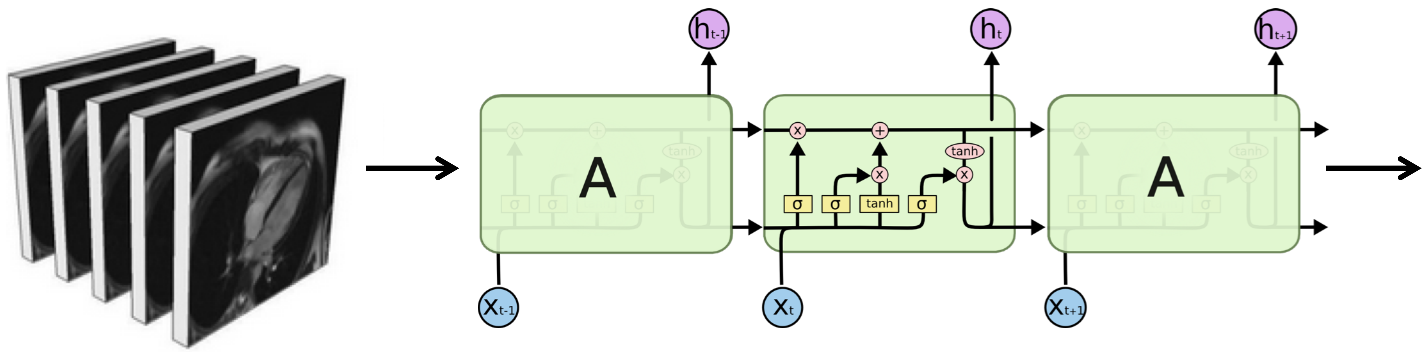
- X_t
  - Current input
- C_{t-1}
  - Memory from last cell
- h_{t-1}
  - Output from last cell
- h_t
  - Current output
- **1: forget gate**
  - Removes info
- **2: input gate**
  - Adds info
- **3: output gate**
  - Selects useful info as output

LSTM Use Case

- **Predicting job status of computer processes**
  - For experiments related to particle physics

LSTM Use Case

Cardiac Image Analysis



Cardiac Function Parameters

References

- **U-Net**
  - Original paper:
    - https://arxiv.org/abs/1505.04597
  - Short description and video:
    - https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/
  - 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
  - U-Net for satellite analysis
    - https://medium.com/vooban-ai/satellite-image-segmentation-a-workflow-with-u-net-7ff992b2a56e

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/

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?