# CARDIAC IMAGE ANALYSIS IN PYTHON

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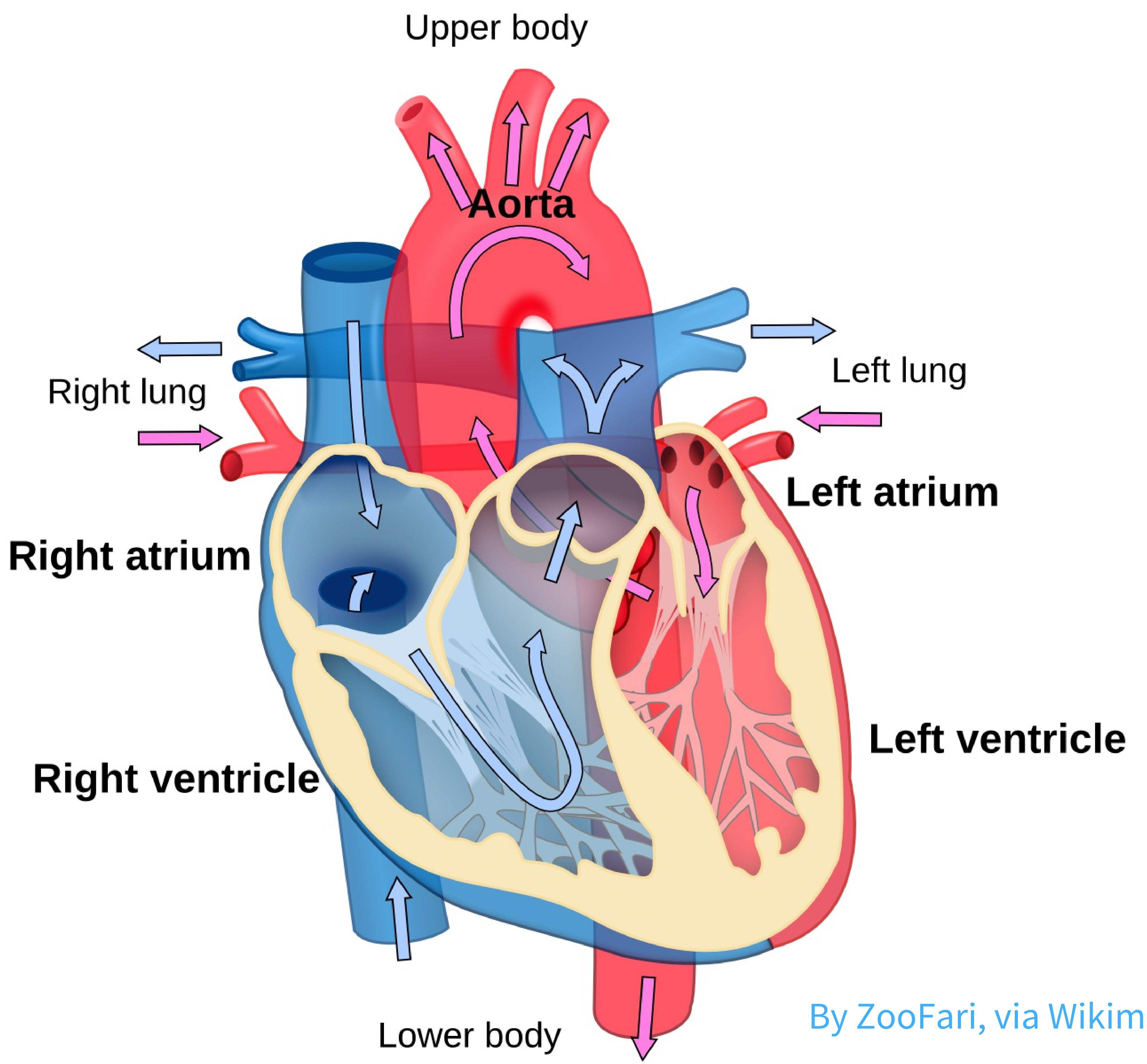
KardioMe

# EVERY 18 SECONDS




By ZooFari, via Wikimedia Commons

# IMAGING IN CARDIOLOGY

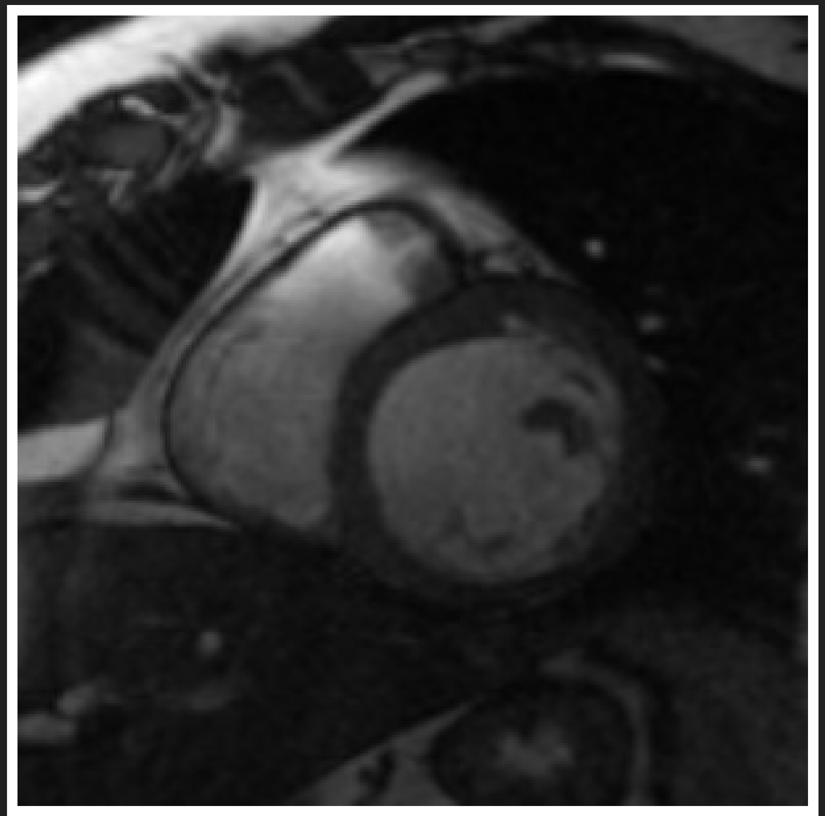
X-Ray

Kelly 2007

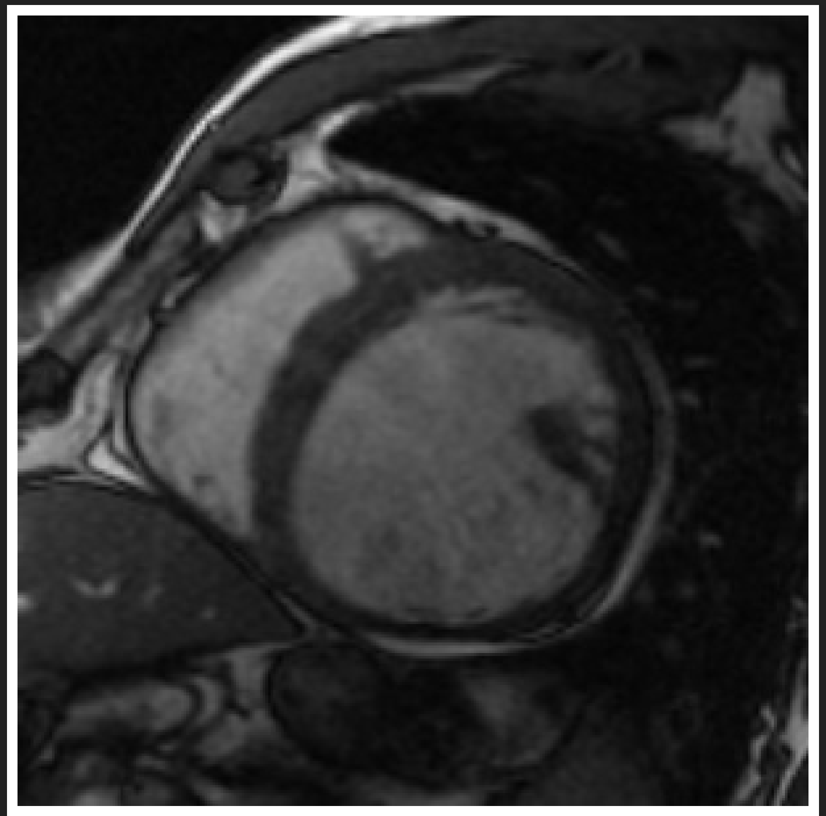
ultrasound

Carmo et al. 2010

# SPOT THE DIFFERENCES

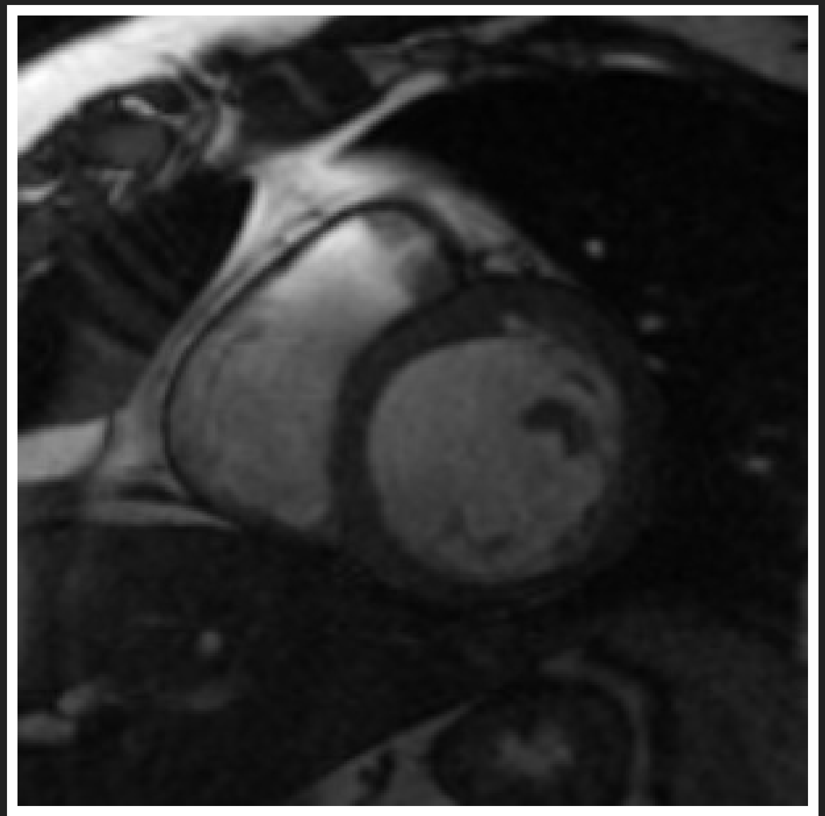


?

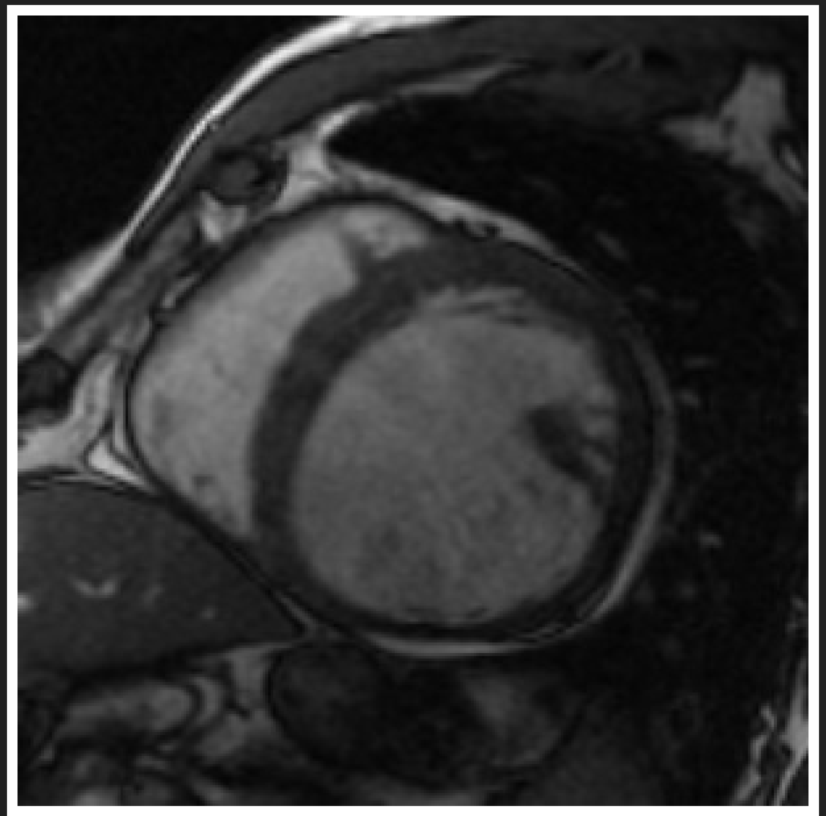


?

# SPOT THE DIFFERENCES

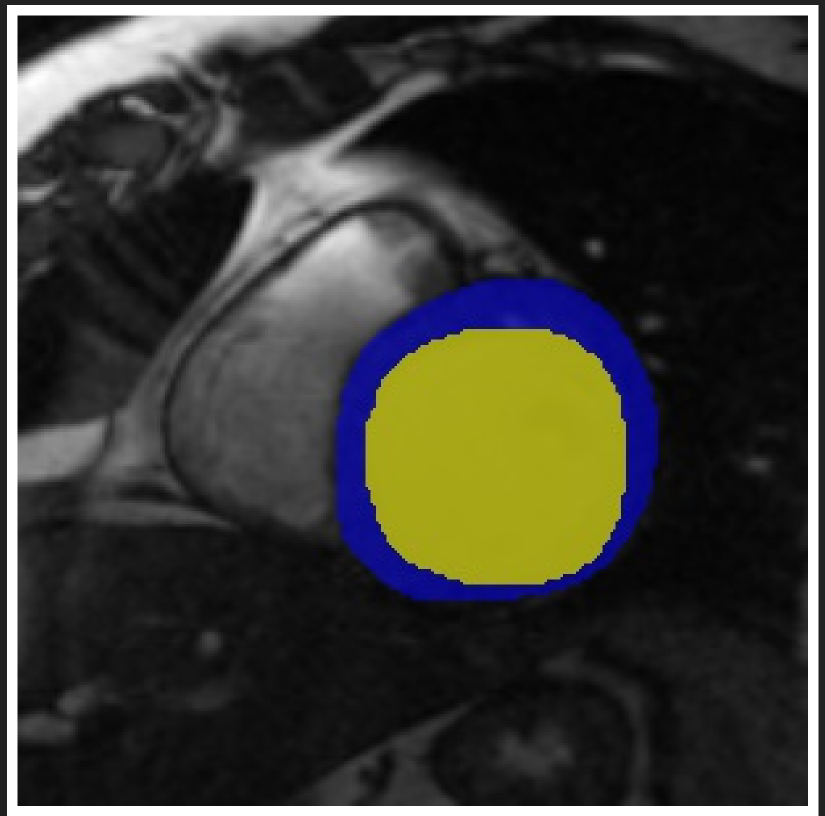


HEALTHY

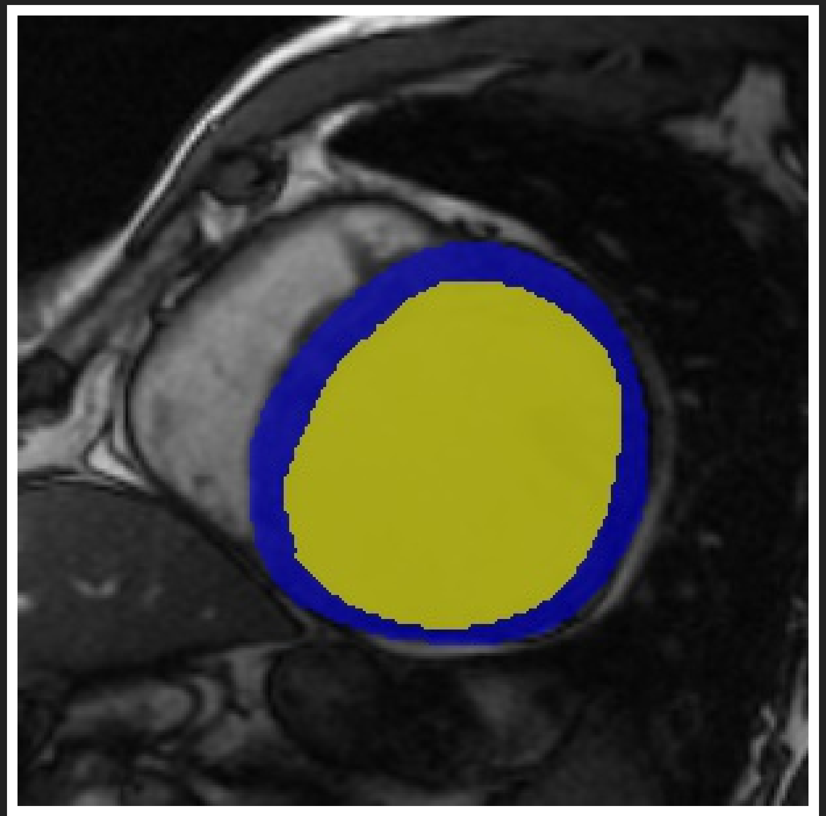


ISCHEMIC HEART FAILURE

# QUANTIFY THE DIFFERENCES

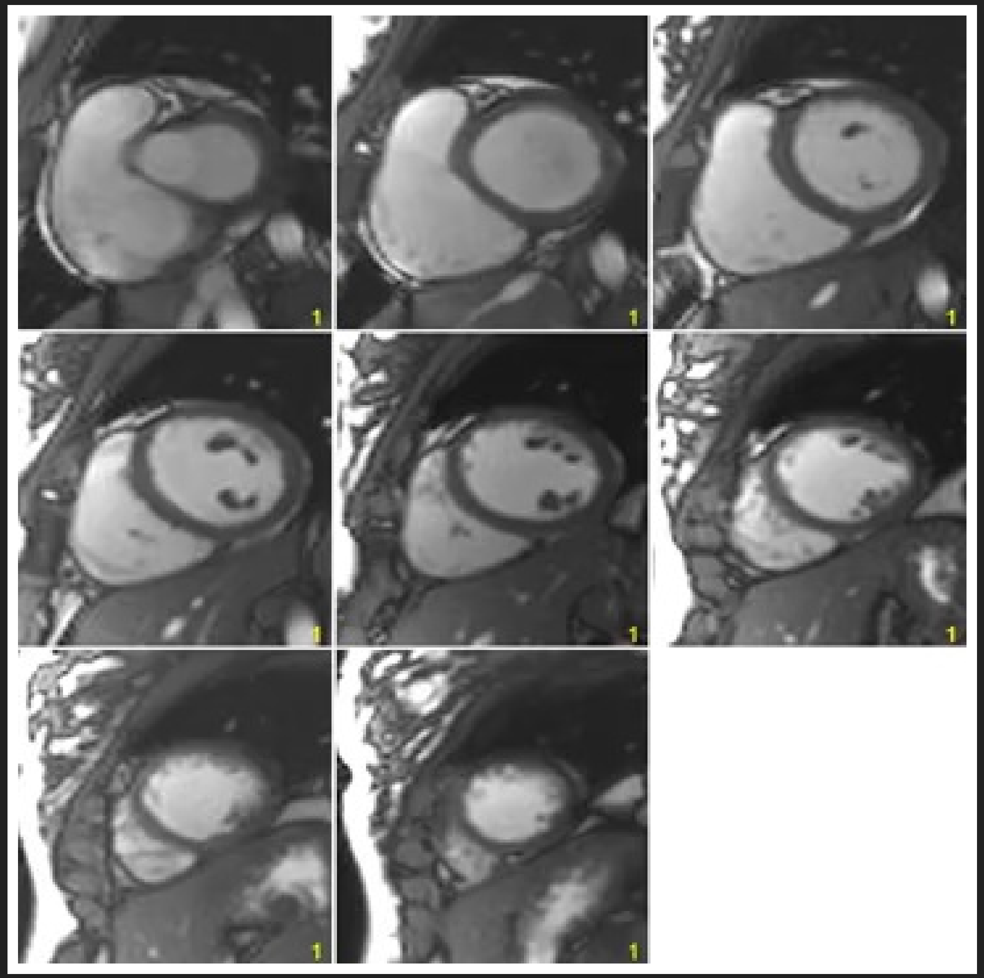


VOLUME: 142 ML

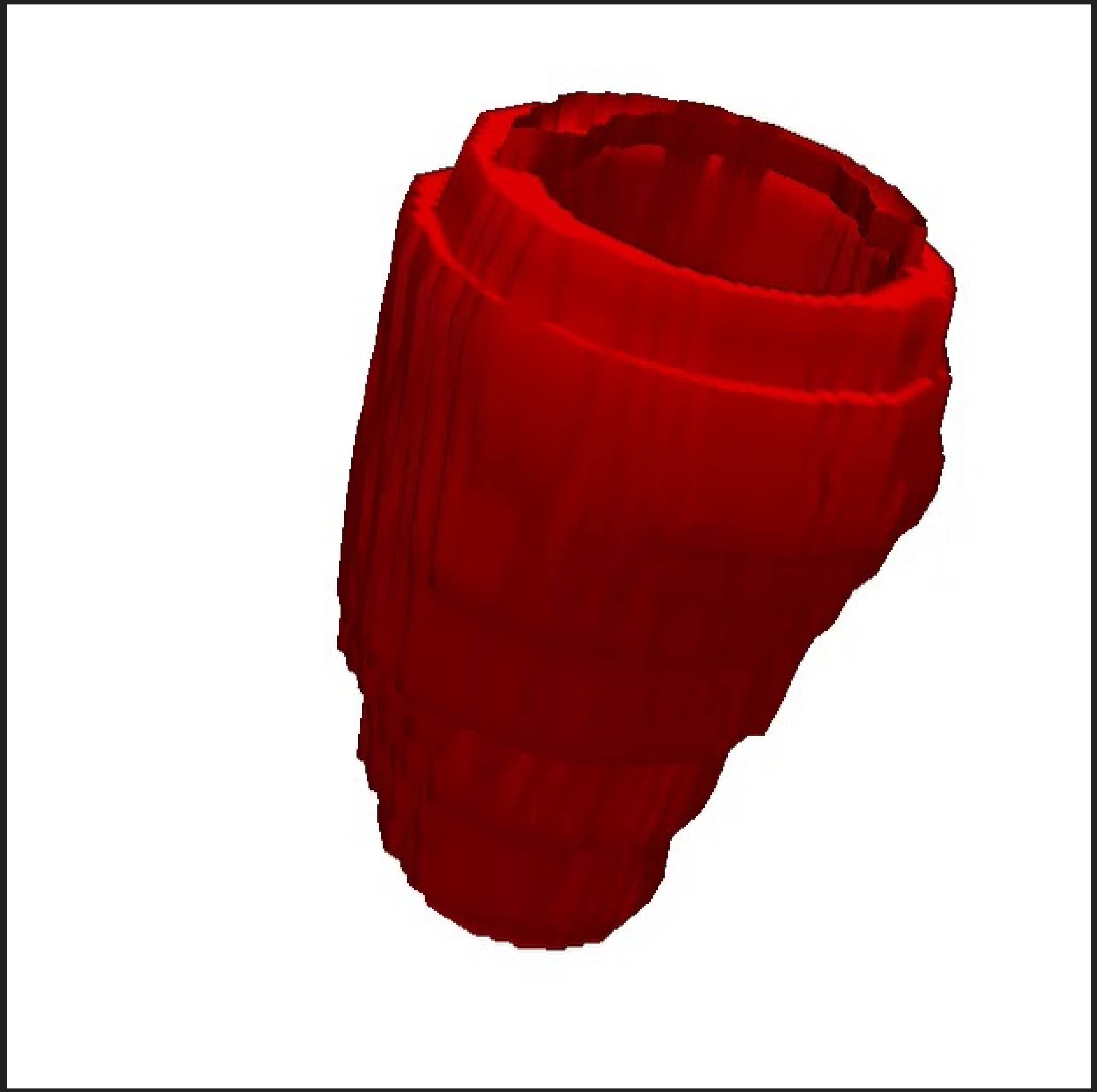


VOLUME: 212 ML

# SEGMENTATION

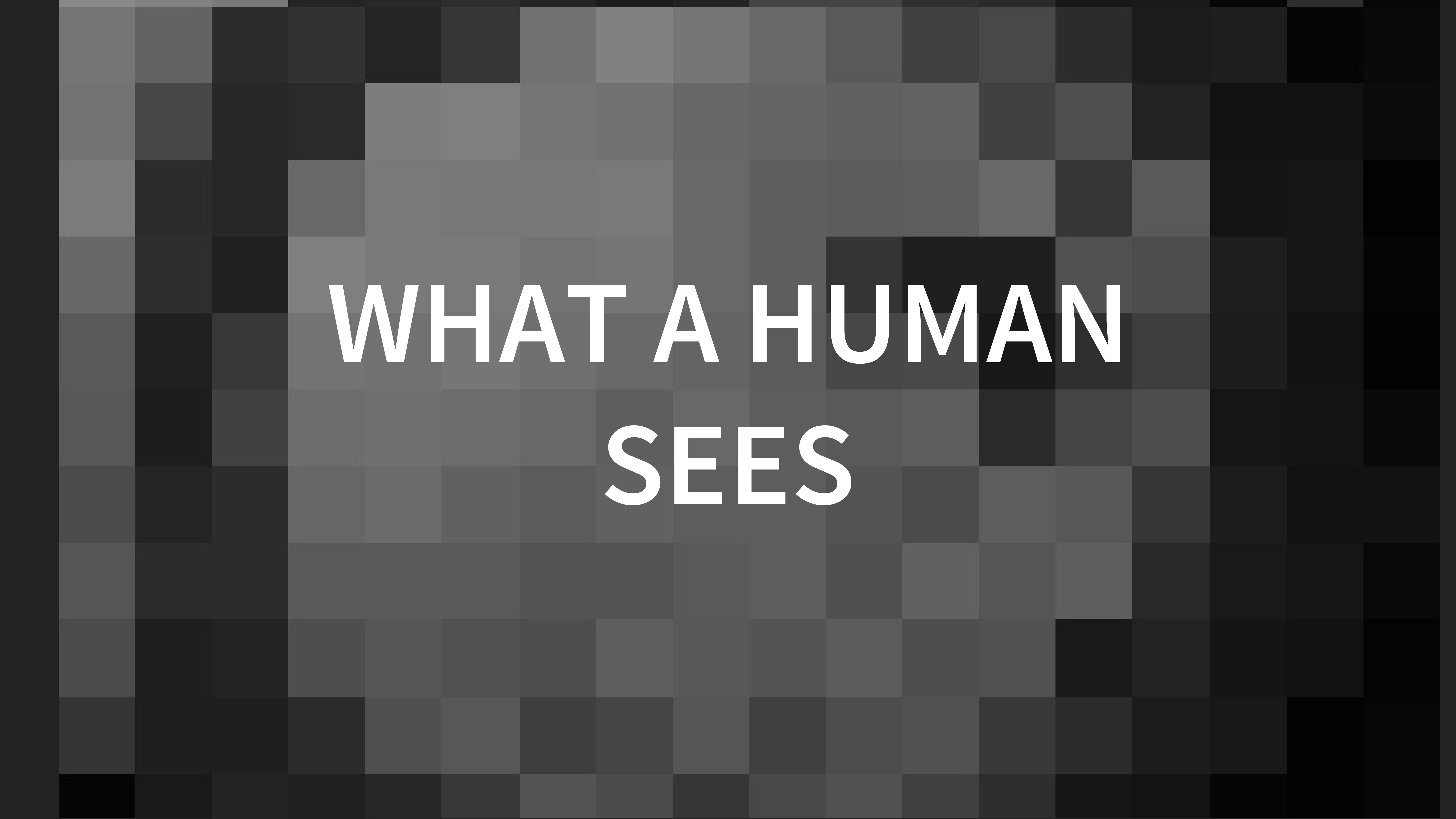


Xue et al. 2013



30 minutes to do manually


WHAT A HUMAN
SEES


WHAT A HUMAN
SEES

# WHAT A COMPUTER SEES

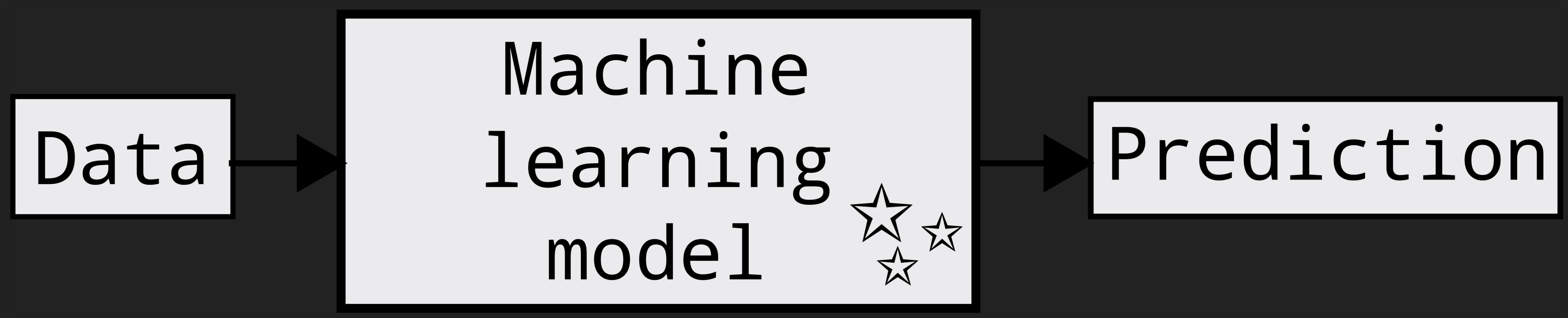
| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 133 | 115 | 57 | 65 | 52 | 69 | 129 | 145 | 134 | 121 | 106 | 81 | 87 | 59 | 42 | 44 | 18 | 24 |
| 131 | 87 | 53 | 57 | 140 | 143 | 133 | 130 | 119 | 117 | 112 | 115 | 81 | 94 | 48 | 31 | 31 | 25 |
| 139 | 59 | 54 | 120 | 138 | 135 | 137 | 139 | 120 | 110 | 107 | 109 | 122 | 68 | 105 | 33 | 36 | 16 |
| 119 | 60 | 46 | 144 | 138 | 138 | 131 | 133 | 120 | 111 | 67 | 45 | 46 | 98 | 91 | 44 | 37 | 18 |
| 106 | 47 | [illegible] | [illegible] | [illegible] | 135 | [illegible] | 122 | [illegible] | [illegible] | 87 | 88 | [illegible] | 62 | 77 | 43 | 32 | 17 |
| 103 | 43 | 80 | 125 | 127 | 124 | 120 | 109 | 120 | 109 | 106 | 110 | 56 | 83 | 92 | 35 | 34 | 24 |
| 90 | 51 | 59 | 118 | 123 | 113 | 107 | [illegible] | [illegible] | [illegible] | 99 | 91 | 108 | 103 | 69 | 43 | 31 | 32 |
| 101 | 60 | 59 | 105 | 105 | 105 | 98 | 99 | 105 | 109 | 95 | 114 | 101 | 110 | 54 | 39 | 36 | 22 |
| 90 | 45 | 49 | 94 | 101 | 96 | 94 | 109 | 104 | 100 | 107 | 93 | 98 | 39 | 49 | 34 | 31 | 18 |
| 67 | 46 | 45 | 58 | 95 | 102 | 77 | 85 | 101 | 79 | 91 | 97 | 71 | 58 | 43 | 38 | 16 | 19 |
| 19 | 39 | 50 | 48 | 54 | 72 | 98 | 91 | 68 | 88 | 97 | 79 | 61 | 36 | 33 | 19 | 17 | 20 |

# WELCOME TO COMPUTER VISION

- Get the blood by thresholding the bright pixels
- Get rid of the arteries
- Separate the circular left ventricle from the right one
- Make sure it works with all hearts
- There are imaging artefacts too!
- Contrast can be poor
- Some hearts do not have both ventricles!

# MACHINE LEARNING

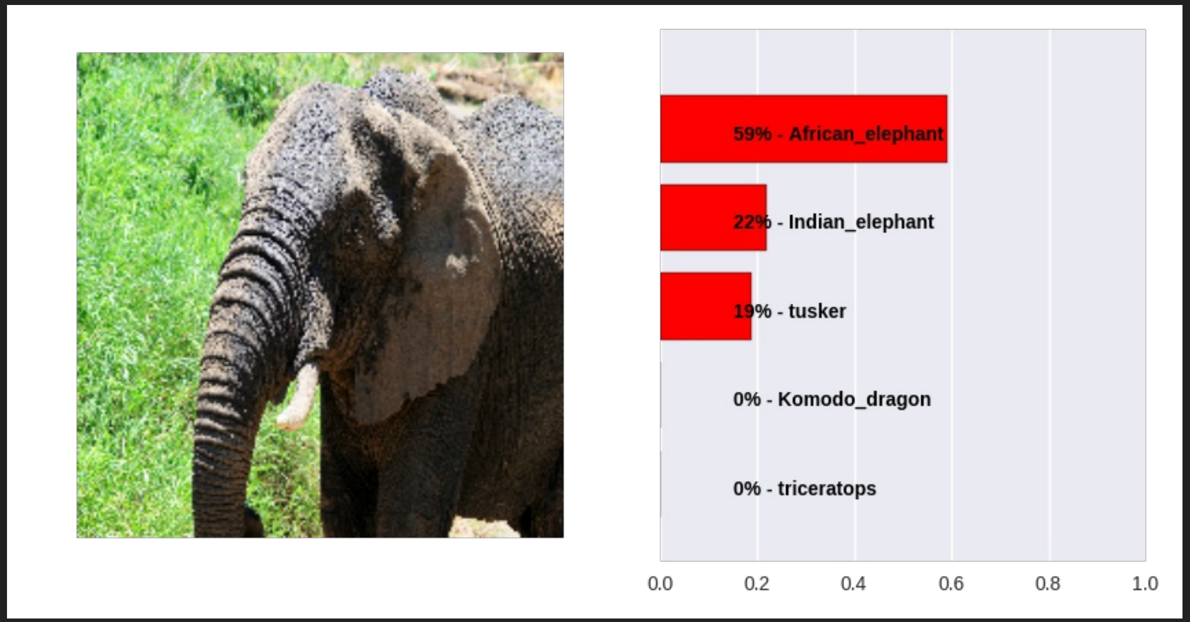
## SOLVING PROBLEMS WITH DATA

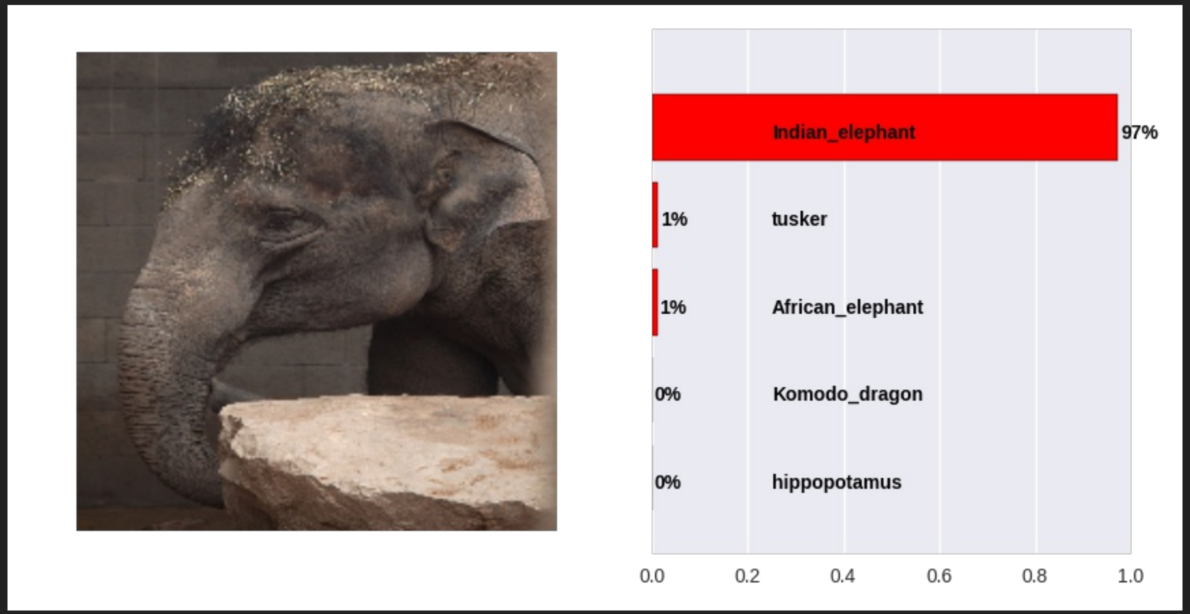



**prediction** = **model**.*predict* (**data**)

# IMAGE RECOGNITION IN 6 LINES OF CODE

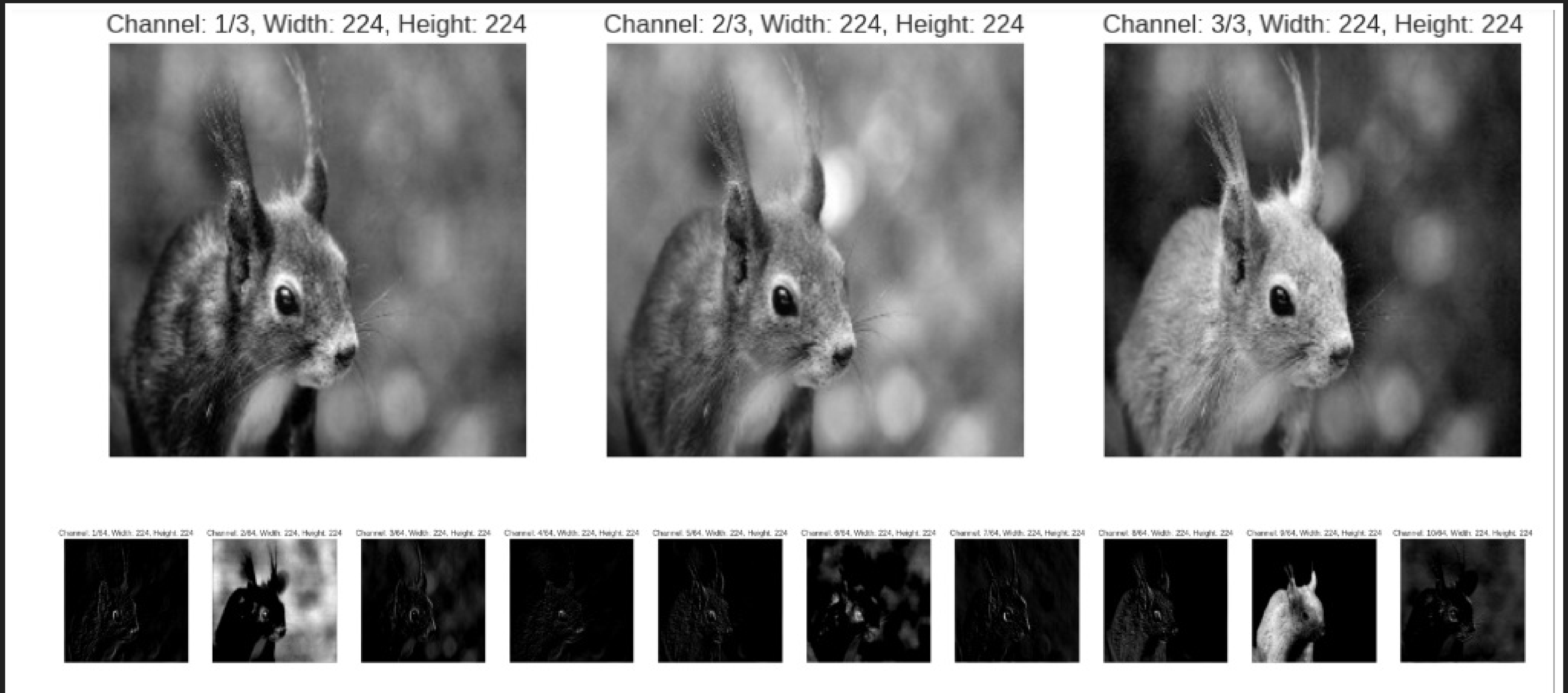
```
from keras.applications import imagenet_utils
from keras.applications.vgg16 import VGG16

# Load and prepare input images
images_raw = load_images()
images = imagenet_utils.preprocess_input(images_raw)

# Load a pretrained image classification model
model = VGG16(include_top=True, weights='imagenet')

# Do the prediction
predictions = model.predict(images)
```




# EXCELLENT FOR NATURAL IMAGES

# FINDING THE IMAGE REPRESENTATION



# EXTRACTING VISUAL FEATURES

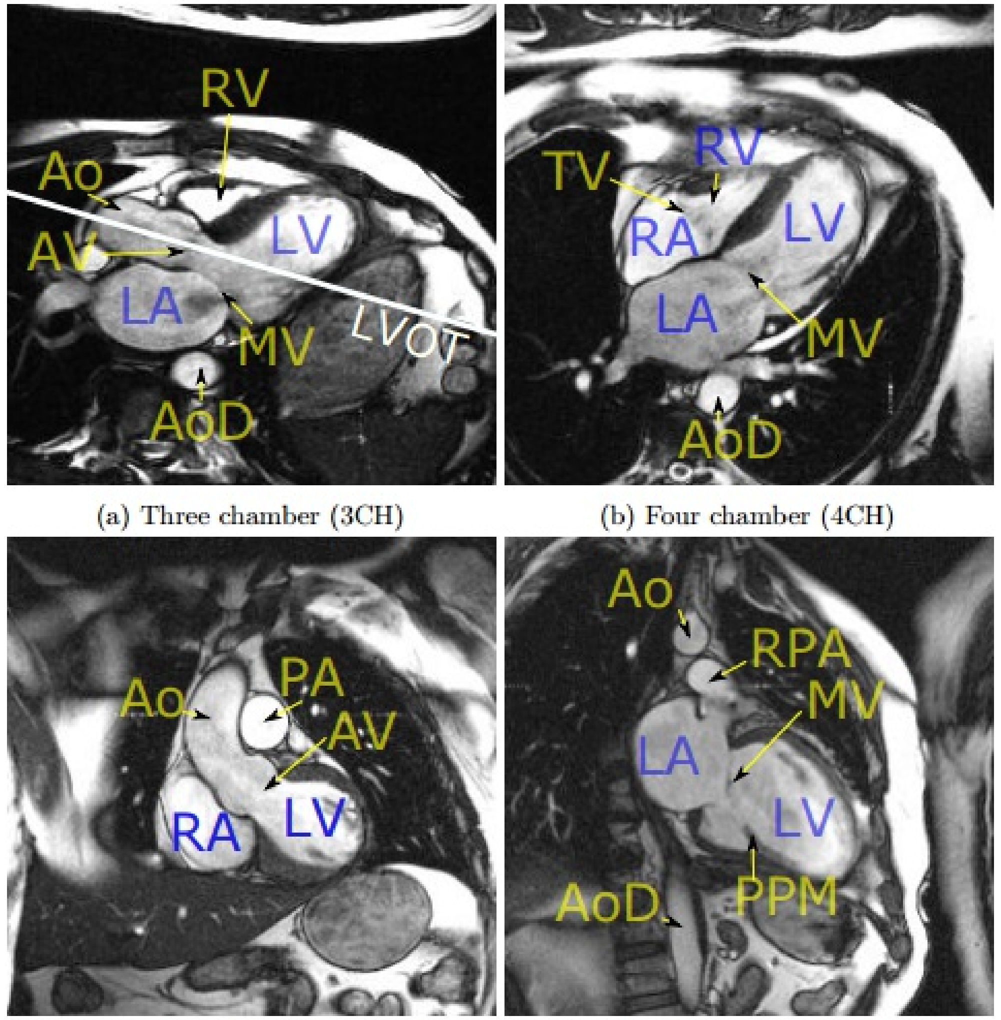
```
# Load a pretrained classification model
source_model = VGG16(weights='imagenet')

# Define feature extractor from one layer of the network
feature_layer = source_model.get_layer('conv4')
feature_extractor = Model(
  input=fix_model.input,
  output=feature_layer.output)

# Extract features
features = feature_extractor.predict(images)
```

See also "Deep visualization toolbox" on youtube

# USING THE FEATURES WITH SCIKIT LEARN

```
from sklearn.svm import LinearSVC
def flatten_features(features):
    return features.reshape(len(features), -1)

features_train = feature_extractor.predict(images_train)
features_train = flatten_features(features_train)
classifier = LinearSVC()
classifier.fit(features_train, labels_train)

# predict on never seen images
features_test = feature_extractor.predict(images_test)
features_test = flatten_features(features_test)
prediction_test = classifier.predict(features_test)
```

# CARDIAC VIEW RECOGNITION




(a) Three chamber (3CH)

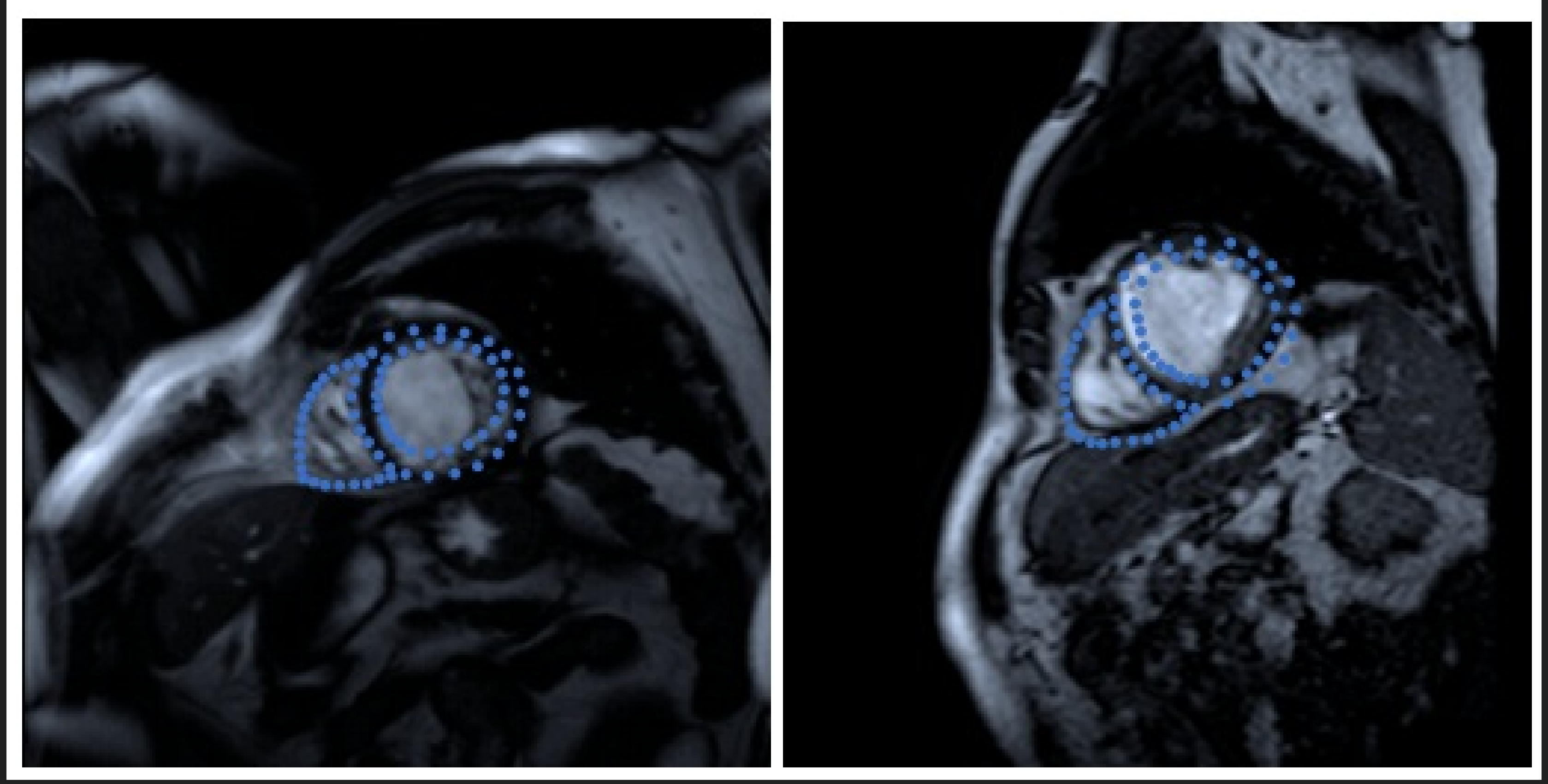
(b) Four chamber (4CH)

(c) Left ventricular outflow tract (LVOT)

(d) Two chamber (2CH)

Margeta et al. 2015, Joint work with Inria and Microsoft Research Cambridge

# LANDMARK REGRESSION



Margeta et al. 2015, Joint work with Inria and Microsoft Research Cambridge

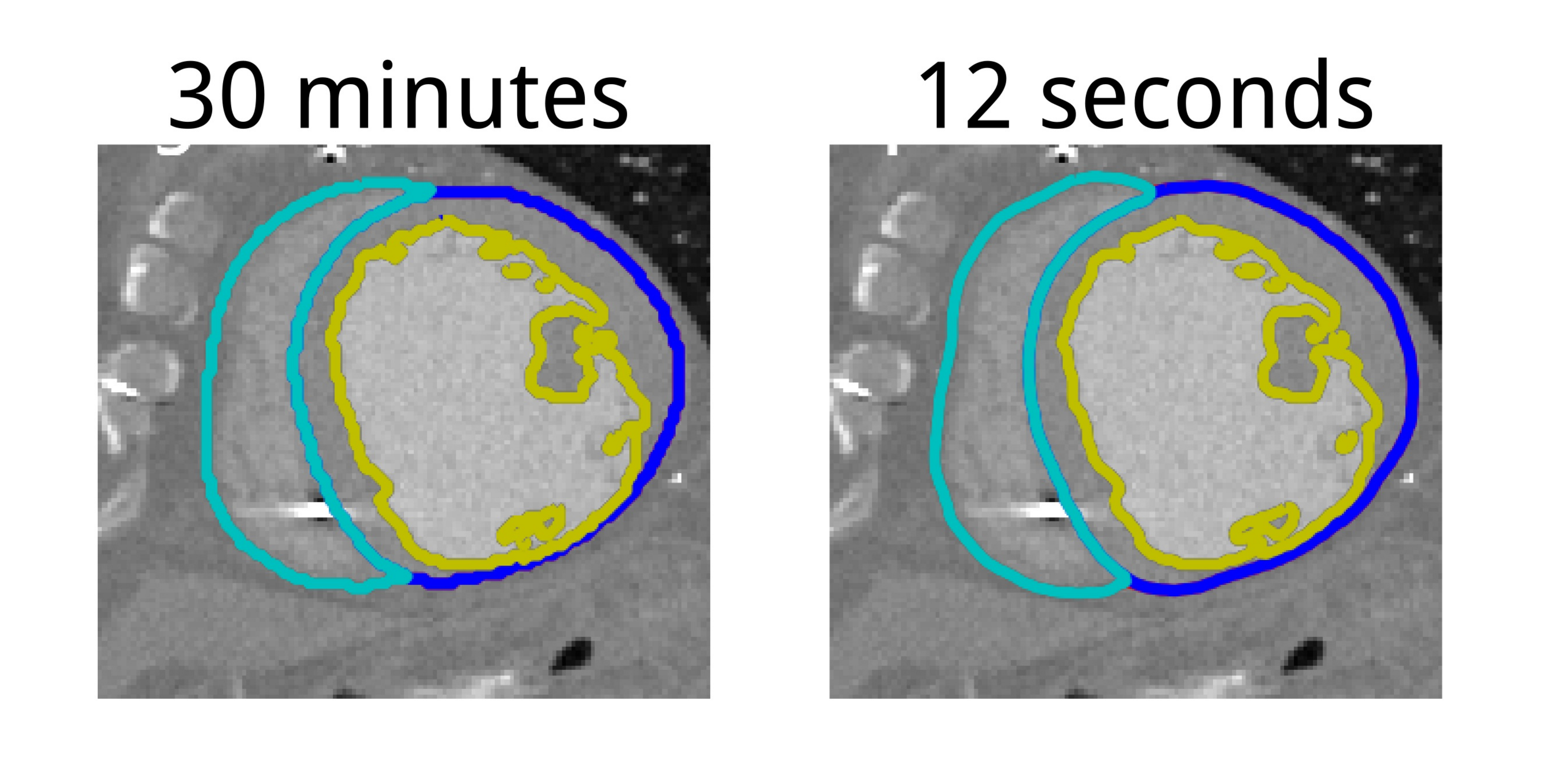
# START FROM SCRATCH

```
from keras.models import Model
from keras.layers import Input, Conv2D, Dense
from keras.layers import GlobalAveragePooling2D

num_outputs = 4
num_filters = 16

# Transformer of a gray image of any size to 16 outputs
input = Input(shape=(1, None, None))
c0 = Conv2D(num_filters, 3, 3, activation='relu')(input)
p = GlobalAveragePooling2D()(c0)
output = Dense(num_outputs, activation='softmax')(p)
model = Model(input=input, output=output)
```

# TRAIN THE MODEL

```
# Loss function - task dependent
# high for bad parameters, low for good ones
# e.g. for image recognition
loss_function = 'sparse_categorical_crossentropy'

# Compile the model and fit
model.compile(loss=loss_function, optimizer='adam')
model.fit(images, labels)

# Save the model for reuse
model.save('model.h5')
```

# LET'S SAVE SOME TIME




- on a GPU

# DEPLOY AS A WEB SERVICE

FLASK (SEE ALSO TENSORFLOW-SERVING)

DOCKER CONTAINERS (SEE ALSO KUBERNETES)

# EXPOSING THE MODEL WITH FLASK

```python
import keras
from flask import Flask, jsonify, request
app = Flask(__name__)
model = keras.models.load_model('model.h5')

@app.route('/predict', methods=['POST'])
def predict():
    X = request_to_numpy(request)
    Y = model.predict(X)
    prediction = convert_prediction(Y)
    return jsonify(output=prediction)

app.run(port=5000, threaded=False)
```

*it requires a little bit more care

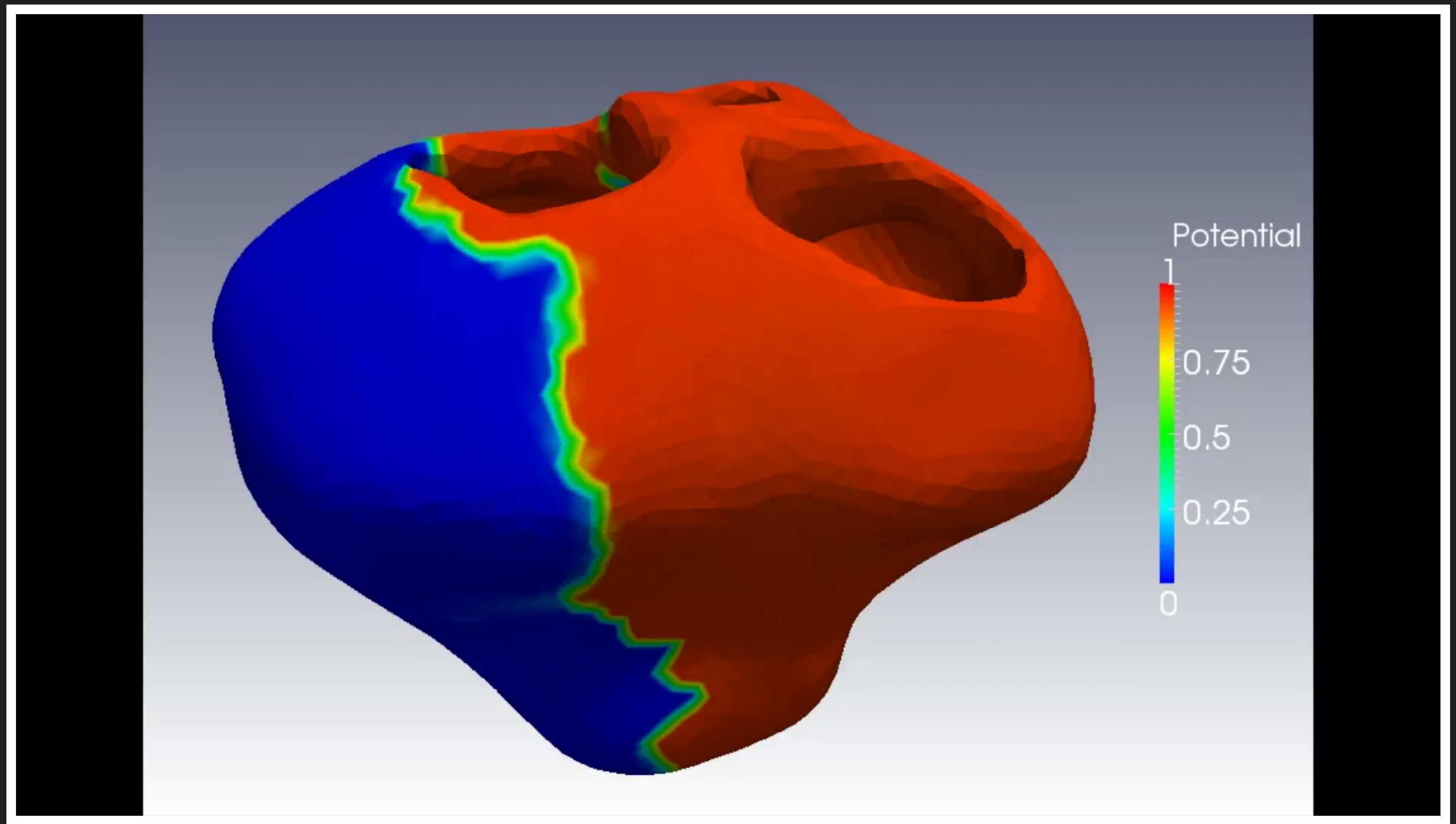
# DEFINE THE DOCKERFILE

```
FROM python:3.5

RUN mkdir -p /usr/src/app
COPY server.py /usr/src/app/
COPY model.h5 /usr/src/app/
COPY requirements.txt /usr/src/app/
WORKDIR /usr/src/app
RUN pip install -r requirements.txt

EXPOSE 5000
CMD python server.py
```

# BUILD AND RUN THE CONTAINER

```
# Build the container
docker build -t kardiome/model-pycon .

# Run the container
docker run -d -p 5000:5000 kardiome/model-pycon

# Call the service
curl -X POST -F 'image=@/data/im.png' localhost:5000/predict
```

# PREDICTING THE FUTURE




Hugo Talbot et al. 2012, Inria

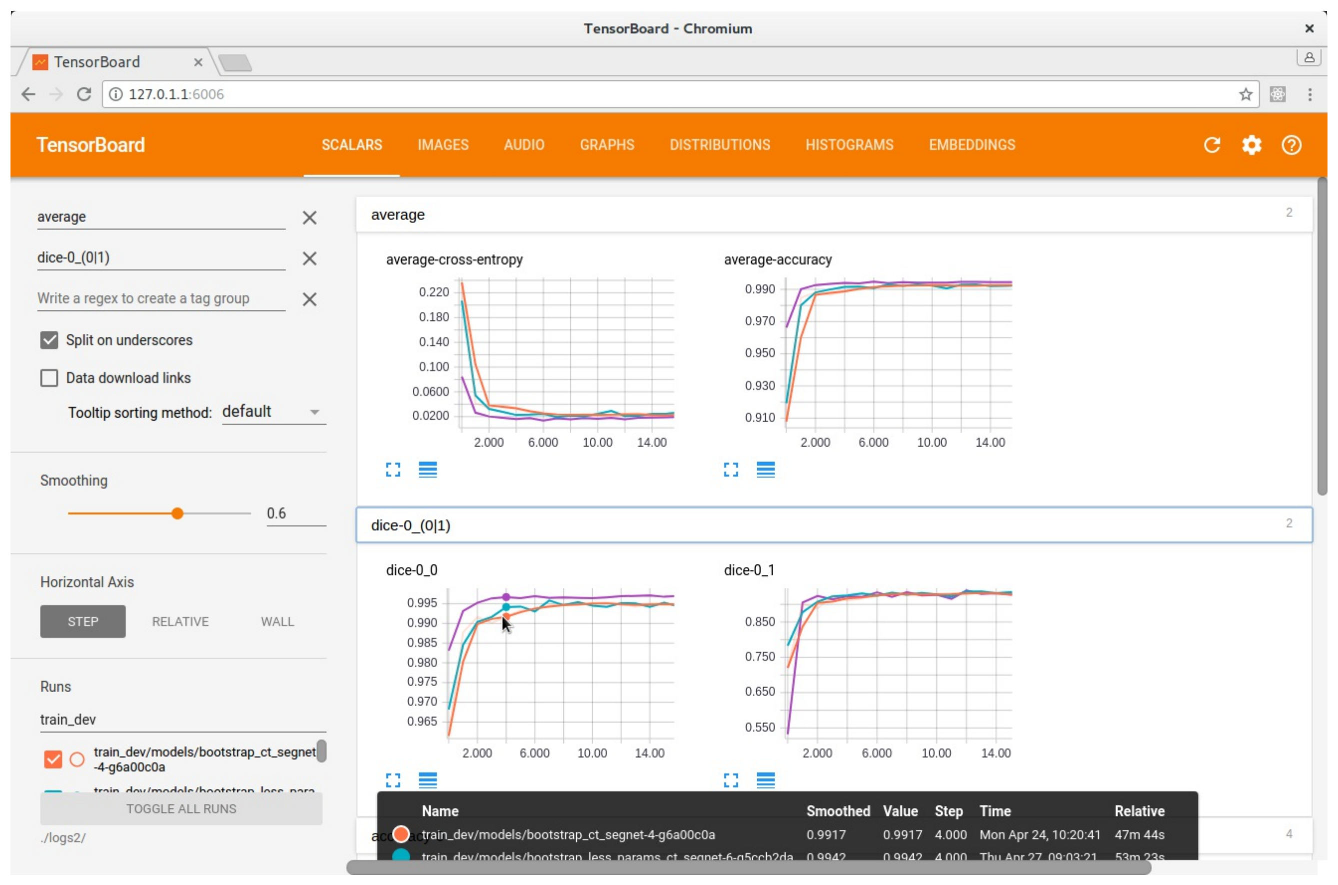
open-source simulation framework

More information

# TIPS TO IMPROVE YOUR MACHINE LEARNING TODAY

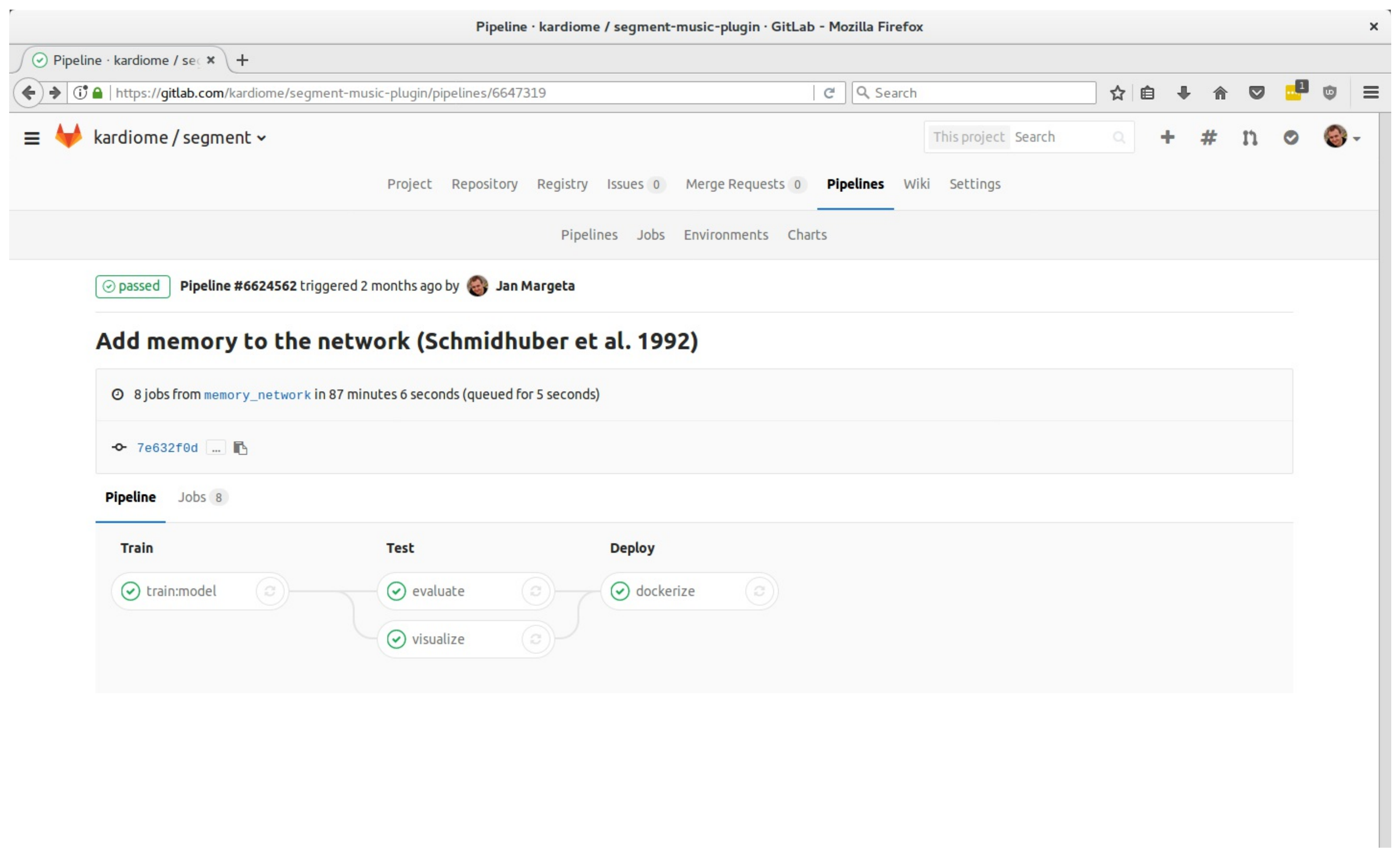
# ITERATE FAST

## ONE METRIC TO RULE THEM ALL




Tensorboard model visualisation

# PROGRESS WITH CONFIDENCE AND REPEATABLE PIPELINES




Gitlab's continuous integration is excellent start for simple pipelines
(see also Airflow, Luigi, Flink)

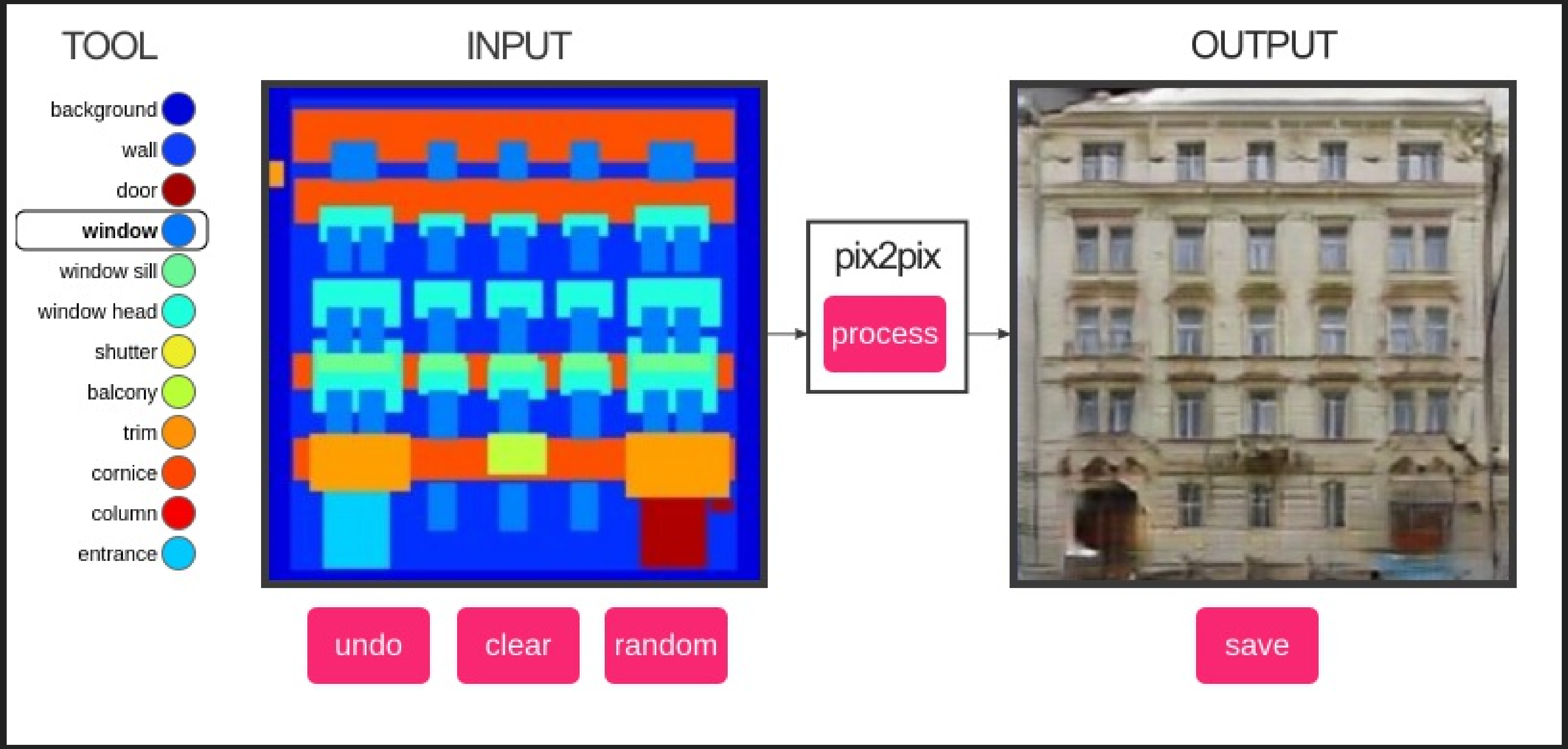
# NO GLORY IN DATA PREPARATION

## BUT IT MUST BE DONE

PostgreSQL

# HAVING A SMALL DATASET?

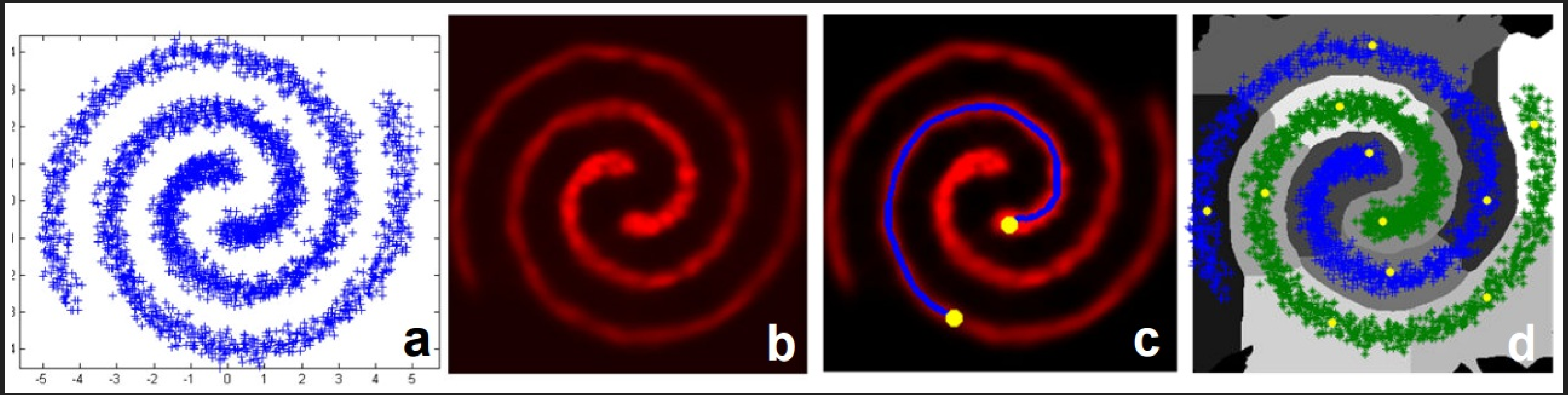
## DO SOMETHING ABOUT IT




https://affinelayer.com/pixsrv/

# GOT UNLABELED DATA?

## DON'T BE LAZY, JUST ANNOTATE IT IF YOU CAN, THERE ARE TOOLS TO HELP YOU



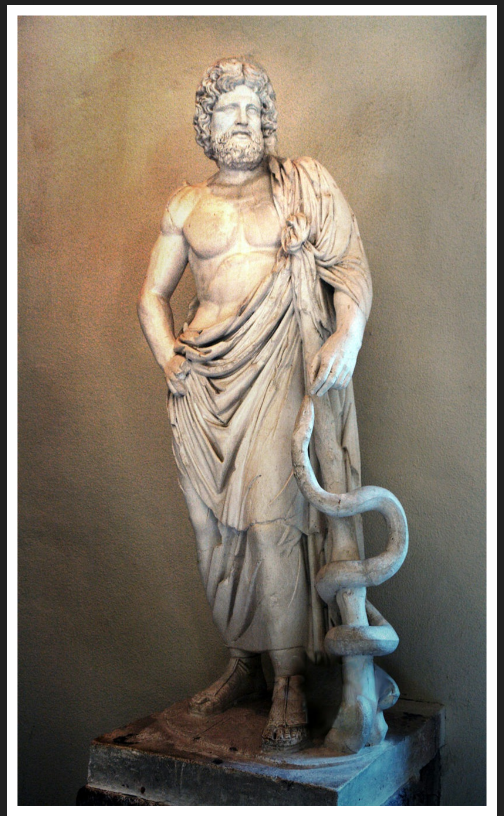

Margeta et al. 2015, Joint work with Inria and Microsoft Research Cambridge

Check out also Scikit learn example on Label Propagation digits active learning or Sloth

# BE PRACTICAL

## HAVE AN OPEN MIND

# PYTHON + AI + MEDICINE = A⚕



# THANKS

Krissy, Hubert, Hugo, Karol, Loïc, Maxime, Rocío, Asclepios, IHU Liryc, Microsoft Research Cambridge, NumFOCUS, PyData

# CONNECT WITH ME

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# CREDITS

- Statue of Asklepius, exhibited in the Museum of Epidaurus Theatre. By original file by Michael F. Mehnert CC BY-SA 3.0, via Wikimedia Commons
- Radau P, Lu Y, Connelly K, Paul G, Dick AJ, Wright GA. “Evaluation Framework for Algorithms Segmenting Short Axis Cardiac MRI.” The MIDAS Journal – Cardiac MR Left Ventricle Segmentation Challenge, http://hdl.handle.net/10380/3070

- Some results come from my PhD thesis funded by Microsoft Research through its PhD Scholarship Programme and by the ERC Advanced Grant MedYMA

# RESOURCES

- PhD thesis - Jan Margeta
- PhD thesis - Rocío Cabrera Lozoya
- PhD thesis - Hugo Talbot
- Book From Andrew Ng
- Fast AI Notebooks and course
- Visualizing convnets
- Conv filter visualization

- Transfer learning with MNIST
- Label propagation with scikit learn
- Keras and pretrained models
- Staying organized - Templates for data science
- Cardiac atlas project
- Sunnybrook cardiac dataset
- UK biobank

- Mimesis team @ Inria
- Asclepios @ Inria
- SOFA - Opensource simulation framework
- Cardiovascular death stats
- Detecting cancer with deep learning
- Dermatologist-level classification of skin cancer with deep neural networks

# REFERENCES


- Kelly, M. D. (2007). Laparoscopic repair of strangulated Morgagni hernia. World Journal of Emergency Surgery. Springer Nature. https://doi.org/10.1186/1749-7922-2-27
- Carmo, P., Andrade, M. J., Aguiar, C., Rodrigues, R., Gouveia, R., & Silva, J. A. (2010, December). Mitral annular disjunction in myxomatous mitral valve disease: a relevant abnormality recognizable by transthoracic echocardiography. Cardiovascular Ultrasound. Springer Nature. https://doi.org/10.1186/1476-7120-8-53
- Arnold, J. R., West, N. E., van Gaal, W. J., Karamitsos, T. D., & Banning, A. P. (2008, May 31). The role of Intravascular Ultrasound in the management of spontaneous coronary artery dissection. Cardiovascular Ultrasound. Springer Nature. https://doi.org/10.1186/1476-7120-6-24

- Foley, P. W., Hamaad, A., El-Gendi, H., & Leyva, F. (2010). Incidental cardiac findings on computed tomography imaging of the thorax. BMC Research Notes. Springer Nature. https://doi.org/10.1186/1756-0500-3-326
- Vanezis, A. P., Baig, M. K., Mitchel, I. M., Shajar, M., Naik, S. K., Henderson, R. A., & Mathew, T. (2011). Pseudoaneurysm of the left ventricle following apical approach TAVI. Journal of Cardiovascular Magnetic Resonance. Springer Nature. https://doi.org/10.1186/1532-429x-13-79
- Xue, H., Kellman, P., LaRocca, G., Arai, A. E., & Hansen, M. S. (2013). High spatial and temporal resolution retrospective cine cardiovascular magnetic resonance from shortened free breathing real-time acquisitions. Journal of Cardiovascular Magnetic Resonance. Springer Nature. https://doi.org/10.1186/1532-429x-15-102
- Margeta, J., McLeod, K., Criminisi, A., & Ayache, N. (2014). Decision Forests for Segmentation of the Left Atrium from 3D MRI. Statistical Atlases and Computational Models of the Heart. Imaging and Modelling Challenges. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-54268-8_6

- Tobon-Gomez, C., Geers, A. J., Peters, J., Weese, J., Pinto, K., Karim, R., … Rhode, K. S. (2015, July). Benchmark for Algorithms Segmenting the Left Atrium From 3D CT and MRI Datasets. IEEE Transactions on Medical Imaging. Institute of Electrical and Electronics Engineers (IEEE). https://doi.org/10.1109/tmi.2015.2398818
- Margeta, J., Criminisi, A., Cabrera Lozoya, R., Lee, D. C., & Ayache, N. (2015, August 13). Fine-tuned convolutional neural nets for cardiac MRI acquisition plane recognition. Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization. Informa UK Limited. https://doi.org/10.1080/21681163.2015.1061448
- McLeod, K., Wall, S., Leren, I. S., Saberniak, J., & Haugaa, K. H. (2016, October 14). Ventricular structure in ARVC: going beyond volumes as a measure of risk. Journal of Cardiovascular Magnetic Resonance. Springer Nature. https://doi.org/10.1186/s12968-016-0291-9

- Talbot, H., Marchesseau, S., Duriez, C., Sermesant, M., Cotin, S., & Delingette, H. (2013, February 21). Towards an interactive electromechanical model of the heart. Interface Focus. The Royal Society. https://doi.org/10.1098/rsfs.2012.0091
- Demarcy, T., Vandersteen, C., Raffaelli, C., Gnansia, D., Guevara, N., Ayache, N., & Delingette, H. (2016). Uncertainty Quantification of Cochlear Implant Insertion from CT Images. Clinical Image-Based Procedures. Translational Research in Medical Imaging. Springer International Publishing. https://doi.org/10.1007/978-3-319-46472-5_4
- Montuoro, A., Waldstein, S. M., Gerendas, B. S., Schmidt-Erfurth, U., & Bogunović, H. (2017, February 27). Joint retinal layer and fluid segmentation in OCT scans of eyes with severe macular edema using unsupervised representation and auto-context. Biomedical Optics Express. The Optical Society. https://doi.org/10.1364/boe.8.001874
- Demarcy, T., Vandersteen, C., Raffaelli, C., Gnansia, D., Guevara, N., Ayache, N., & Delingette, H. (2017). Automated Analysis of Human Cochlea Shape Variability from segmented μCT images. Computerized Medical Imaging and Graphics (to appear).

- Radau, P., Lu, Y., Connelly, K., Paul, G., Dick, AJ., Wright, GA. (2009). Evaluation Framework for Algorithms Segmenting Short Axis Cardiac MRI. The MIDAS Journal – Cardiac MR Left Ventricle Segmentation Challenge. http://hdl.handle.net/10380/3070
- Kadish, A. H., Bello, D., Finn, J. P., Bonow, R. O., Schaechter, A., Subacius, H., … Goldberger, J. J. (2009, September). Rationale and Design for the Defibrillators to Reduce Risk by Magnetic Resonance Imaging Evaluation (DETERMINE) Trial. Journal of Cardiovascular Electrophysiology. Wiley-Blackwell. https://doi.org/10.1111/j.1540-8167.2009.01503.x
- Fonseca, C. G., Backhaus, M., Do Chung, J., Tao, W., Medrano-Gracia, P., Cowan, B. R., … Young, A. A. (2010). The Cardiac Atlas Project: Rationale, Design and Procedures. Statistical Atlases and Computational Models of the Heart. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-15835-3_4