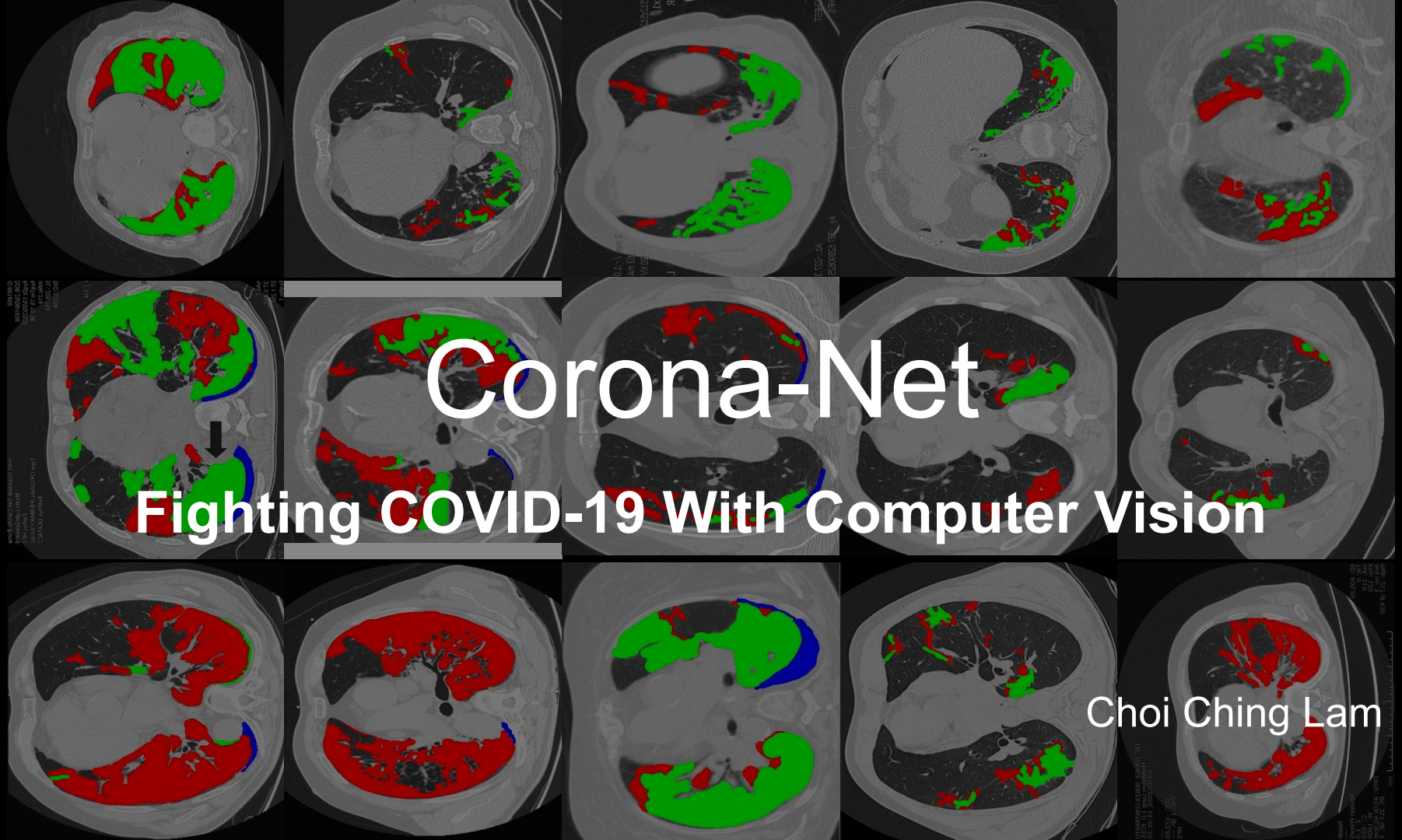


Corona-Net

Fighting COVID-19 With Computer Vision

Choi Ching Lam

Self Intro

- Choi Ching Lam
- 17 year old, Form 5 student from Hong Kong
- Favourite languages: Python, Julia
- Currently interning at NVIDIA's AI Tech Center
- Into Computer Vision, aspires to become a researcher
- Email: ccl5a09@gmail.com
- https://github.com/chinglamchoi
- https://medium.com/@cchoi314

Background

- Inspired by doctors from Wuhan on TV
- Inspired by Johns Hopkins University's (Center for Systems Science and Engineering (CSSE)) COVID-19 Dashboard
- Relevant to previous work on brain tumour boundary resection for lower grade glioma

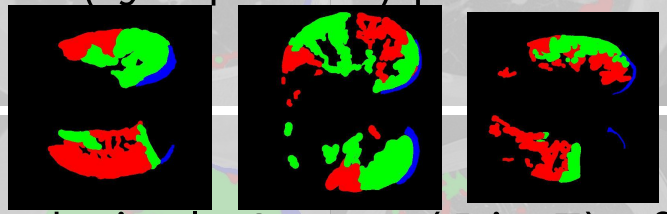
Problem Statement

- Hospitals are overwhelmed with COVID-19 patients
  - Manpower shortage → Doctors (esp radiologists), etc
  - Supplies shortage → ventilators, masks, etc
- **Solution**: **Automate CT diagnosis confirmation with AI**
  - Determine severity → Triage patients, allocate supplies
  - Gauge mortality probability
  - (Future) Design personalised treatment

Corona-Net

1. **Binary Classification**
    a. Infected (1) / not-infected (0) with COVID-19
2. **Binary Segmentation:**

    a. Predict all infected (symptoms) pixels of COVID-19 in CT
3. **3-Class Segmentation:**

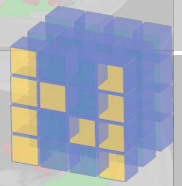


    a. Predict all infected pixels & type (1 in 3) of symptoms:

    ground glass, consolidation, pleural effusion

Technologies Used

- Language: Python with NumPy library



NumPy

- AI library: PyTorch
- Image processing libraries: Albumentations, Torchvision, Scikit-image, Matplotlib

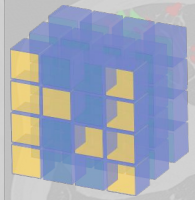
matplotlib

PyTorch

scikit-image
image processing in python

Python with NumPy

- Speed: dynamically typed
- NumPy: parallelism & vectorisation
- NumPy: better support for matrices & tensors & operations
- Easy to prototype with, elegant syntax
- Powerful libraries



NumPy

What to use for Image Processing?

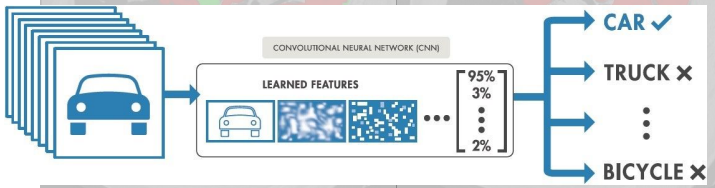
- Matplotlib vs. Scikit-image vs. Torchvision vs. Albumentations
- Matplotlib: General purpose
- Scikit-image: Advanced algorithms
- Torchvision: Tight integration with PyTorch
- Albumentations: Biomedical Imaging

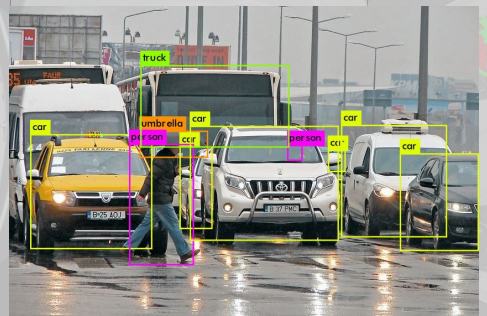
Why PyTorch?

- More research / academia support
- Better customisation ability
- Similar to NumPy
- Dynamism e.g. Dynamic computation graphs

Model Architecture

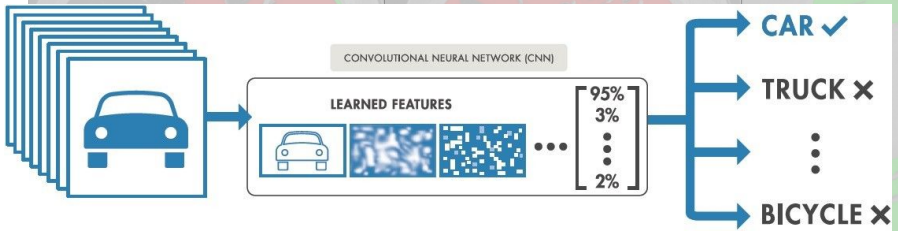
- For multi-label segmentation
- Classification vs. detection vs. segmentation
- Classification: Input image → output class label
- Detection: Input image → output bounding box & class label
- Segmentation: Input image → output image mask

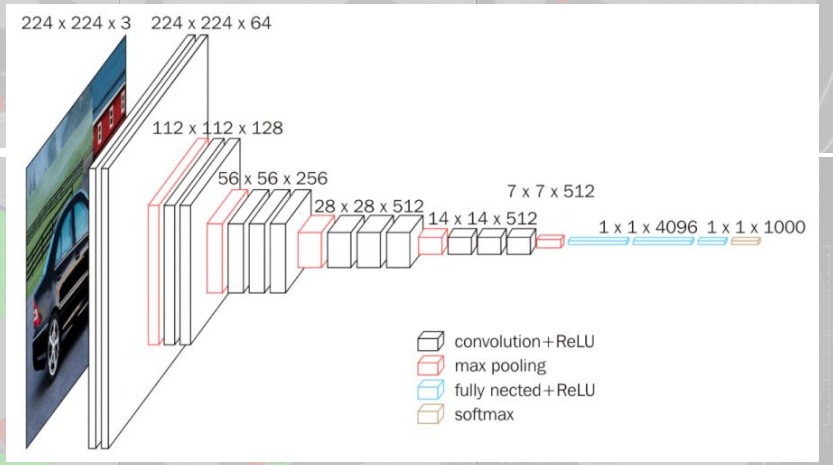




Classification

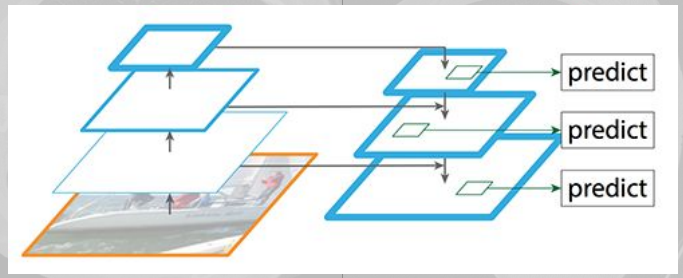
- Input image → output class label (FC layer)
- Can use vanilla Convolutional Neural Networks
- Deep CNNs: accuracy saturation & degradation problem
  - Residual Networks
  - Feature Pyramid Networks





Classification

- ResNets: Shortcut connections
  - Relieves pressure from added deep layers when identity mapping
- FPNs: lateral, top-down connections
  - Fuses feature maps at different scales
  - Each feature map retains local & global information



Efficient-Net

- Introduce novel Compound Scaling Method
  - Joint scaling of network 1) depth, 2) width, 3) input resolution

$$\text{depth: } d = \alpha^\phi$$

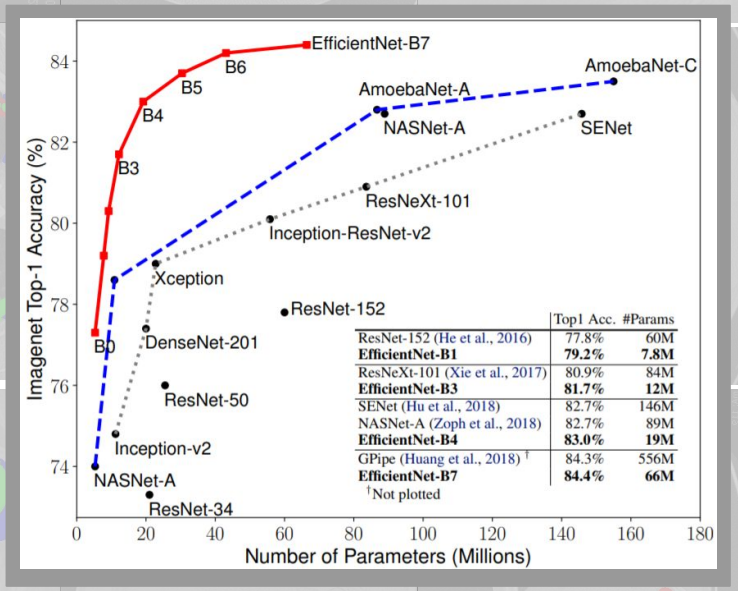
$$\text{width: } w = \beta^\phi$$

$$\text{resolution: } r = \gamma^\phi$$

$$\text{s.t. } \alpha \cdot \beta^2 \cdot \gamma^2 \approx 2$$

$$\alpha \geq 1, \beta \geq 1, \gamma \geq 1$$

Upscale computational resources & FLOPS by 2^ϕ



	Top1 Acc.	#Params
ResNet-152 (He et al., 2016)	77.8%	60M
EfficientNet-B1	**79.2%**	**7.8M**
ResNeXt-101 (Xie et al., 2017)	80.9%	84M
EfficientNet-B3	**81.7%**	**12M**
SENet (Hu et al., 2018)	82.7%	146M
NASNet-A (Zoph et al., 2018)	82.7%	89M
EfficientNet-B4	**83.0%**	**19M**
GPipe (Huang et al., 2018)†	84.3%	556M
EfficientNet-B7	**84.4%**	**66M**

†Not plotted

SOTA on ImageNet with fewer parameters (less complexity) → more computationally efficient

Segmentation

- Image Segmentation (binary, multi-class), semantic segmentation

Binary Segmentation

Algorithm 1 Binary Segmentation

Result: Binary image mask $M \in \mathbb{R}^{H \times W}$

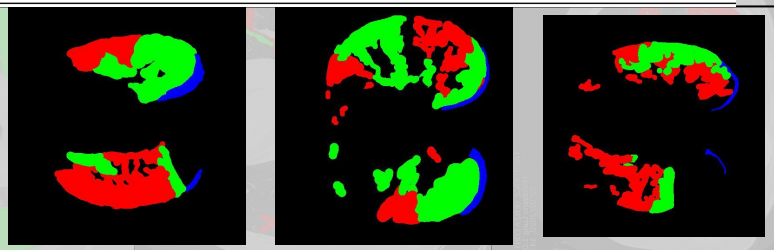
```
for pixel in CT_scan_slice do
    if pixel == infected with COVID-19 then
        pixel ← 1
    else
        pixel ← 0
    end
end
```

Multi-class Segmentation

Algorithm 1 Multi-Class Segmentation

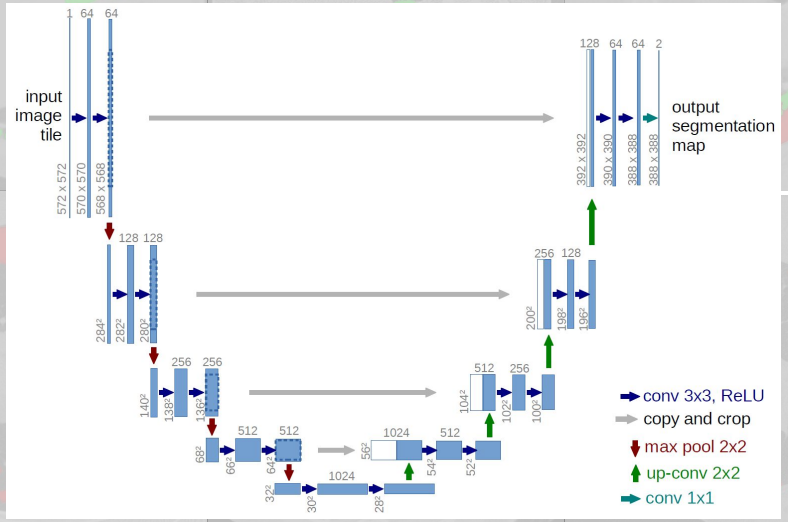
Result: 3D image mask $M \in \mathbb{R}^{3 \times H \times W}$

```
for pixel in CT_scan_slice do
    if pixel == infected with Ground_glass then
        pixel ← 1
    else if pixel == infected with Consolidation then
        pixel ← 2;
    else if pixel == infected with Pleural_effusion then
        pixel ← 3;
    else
        pixel ← 0 ;
    end
end
```



Fully Convolutional Networks

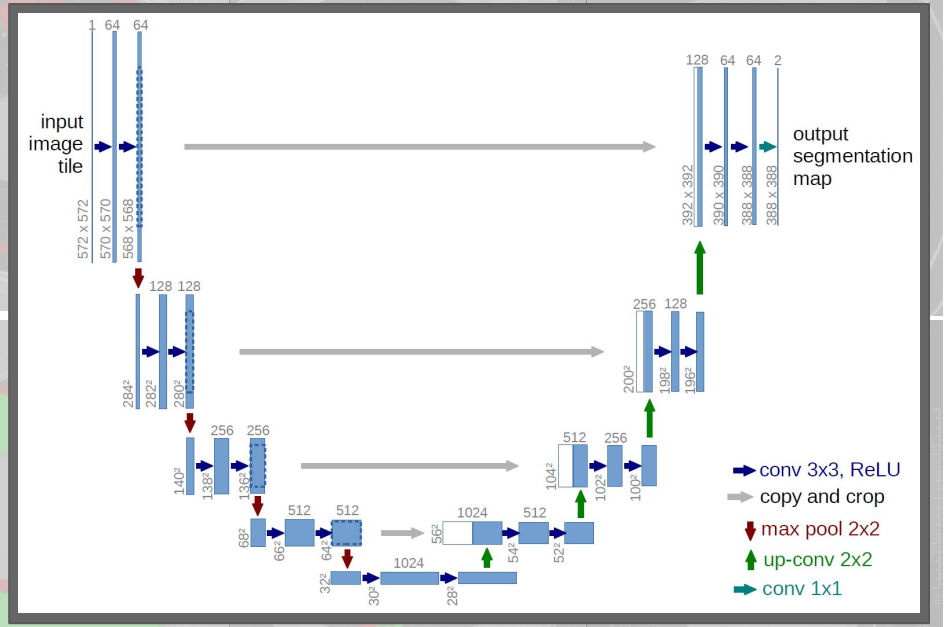
- Used in Corona-Net
- Encoder-decoder network



- Learns convolutional filter directly not function
- U-Net: FCN for biomedical imaging with symmetrical upsampling & downsampling paths, SOTA

U-Net

- Introduce symmetrical contracting & expansive path
- A Fully-Convolutional Network → Computes convolutional filter instead of function
- SOTA in ISBI Challenges
- Tailored to biomedical imaging
- Successful fusion of local to global, spatial-semantic features



Data & Augmentation

- COVID-19 CT segmentation dataset
  - http://medicalsegmentation.com/covid19/
- Augmentation for better generalisation to latent data:
  - Elastic Transformations & Scale Shift ➔ simulate natural deformations of human biological tissue
  - Random cropping ➔ shift invariance
  - Normalisation ➔ grey value invariance
  - Random rotations ➔ rotational invariance

Segmentation Evaluation

Evaluation Metrics

1. Dice Coefficient {[0, 1] with 1 best}

$$Dice = \frac{2\,|A \cap B|}{|A| + |B|}$$

2. Rand Loss {[0, 1] with 0 best}

$$RI = \frac{a+d}{\binom{n}{2}},\quad RE = 1 - RI$$

Accuracies & Losses (1: binary, 2: multi-class)

Dice Coefficient	Rand Loss	Optimiser	Learning Rate
0.5641	0.2167	Adam	1e-02
0.7374	0.1031	Adam	1e-03
0.7965	0.0766	Adam	1e-04
0.4745	0.1591	Adam	1e-05

Dice Coefficient	Rand Loss	Optimiser	Learning Rate
0.5160	0.2490	Adam	1e-02
0.5900	0.2114	Adam	1e-03
0.6160	0.1985	Adam	1e-04
0.5001	0.2565	Adam	1e-05

Future Development

- Recommend Personalised Medicine / Treatment
  - Based on extent (area) and occurrence of particular symptoms of each COVID-19 patient
- Weakly-supervised segmentation
  - Using Global Average Pooling & Object Region Mining
  - No need for labour-intensive mask annotations

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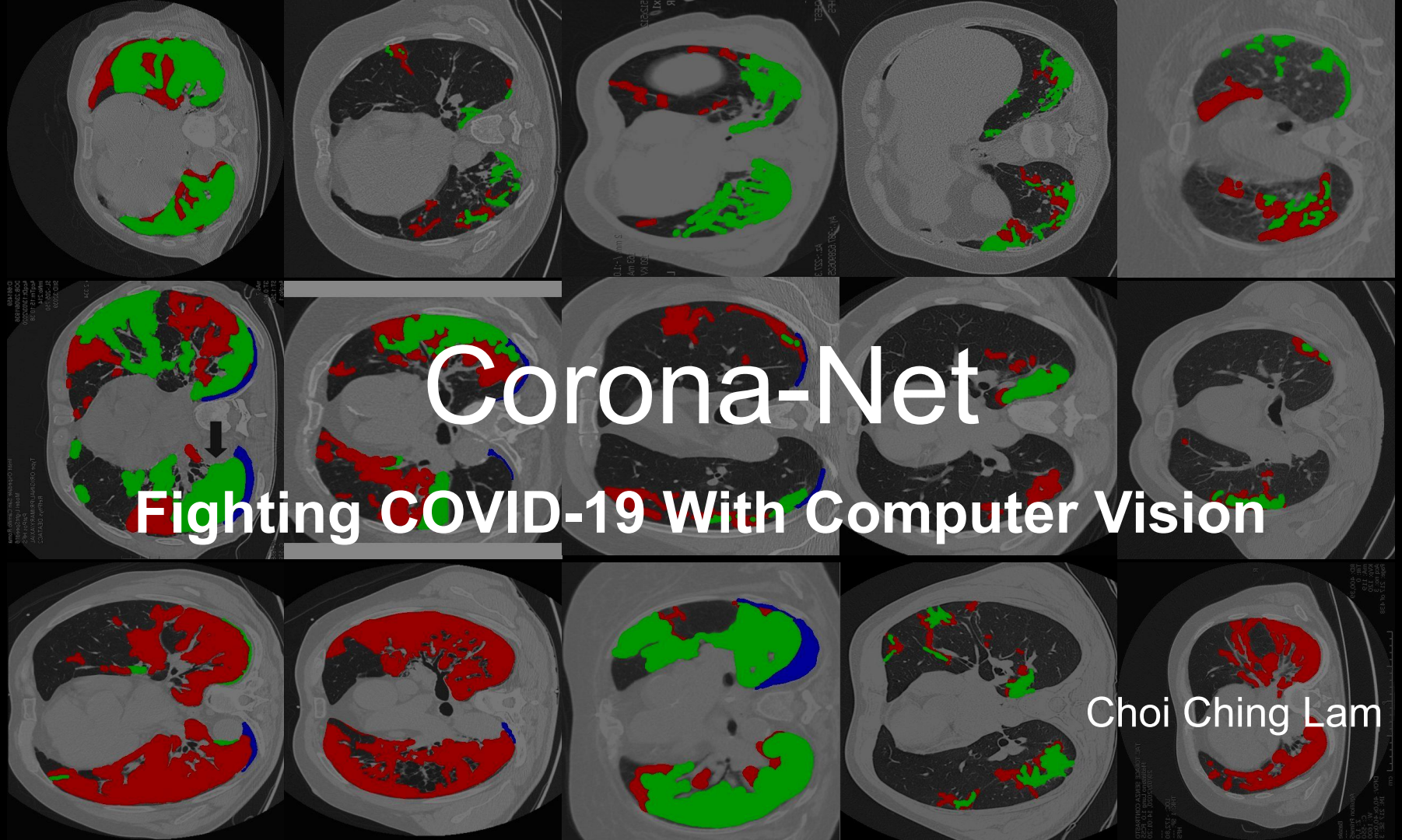
Contact Me

- Choi Ching Lam
- Email: ccl5a09@gmail.com
- https://github.com/chinglamchoi
- https://medium.com/@cchoi314
- https://www.linkedin.com/in/ching-lam-choi-7609541a0/
- https://twitter.com/cchoi314

AI Code-In

- Hong Kong **non-profit** (registering) co-founded by myself and Minnie Chan
- Founded to **enhance the AI literacy of middle/high school students globally** through 2 initiatives: **1) AI Code-In contest & 2) AI lectures/tutorials**
  - 1) Annual 1.5 months long global competition, where students receive mentorship from AI organisations & professionals
  - 2) In-person (after COVID-19) & remote AI tutorials, webinars and lectures for students. Our team will tutor students on AI concepts (e.g. CNNs, LSTMs, attention), while invited speakers (industry professionals, professors) guest lecture on AI-related topics
- **We are currently recruiting organisations, projects & mentors!**
  - https://aicode-in.github.io/AICode-In
  - aicodein.org@gmail.com



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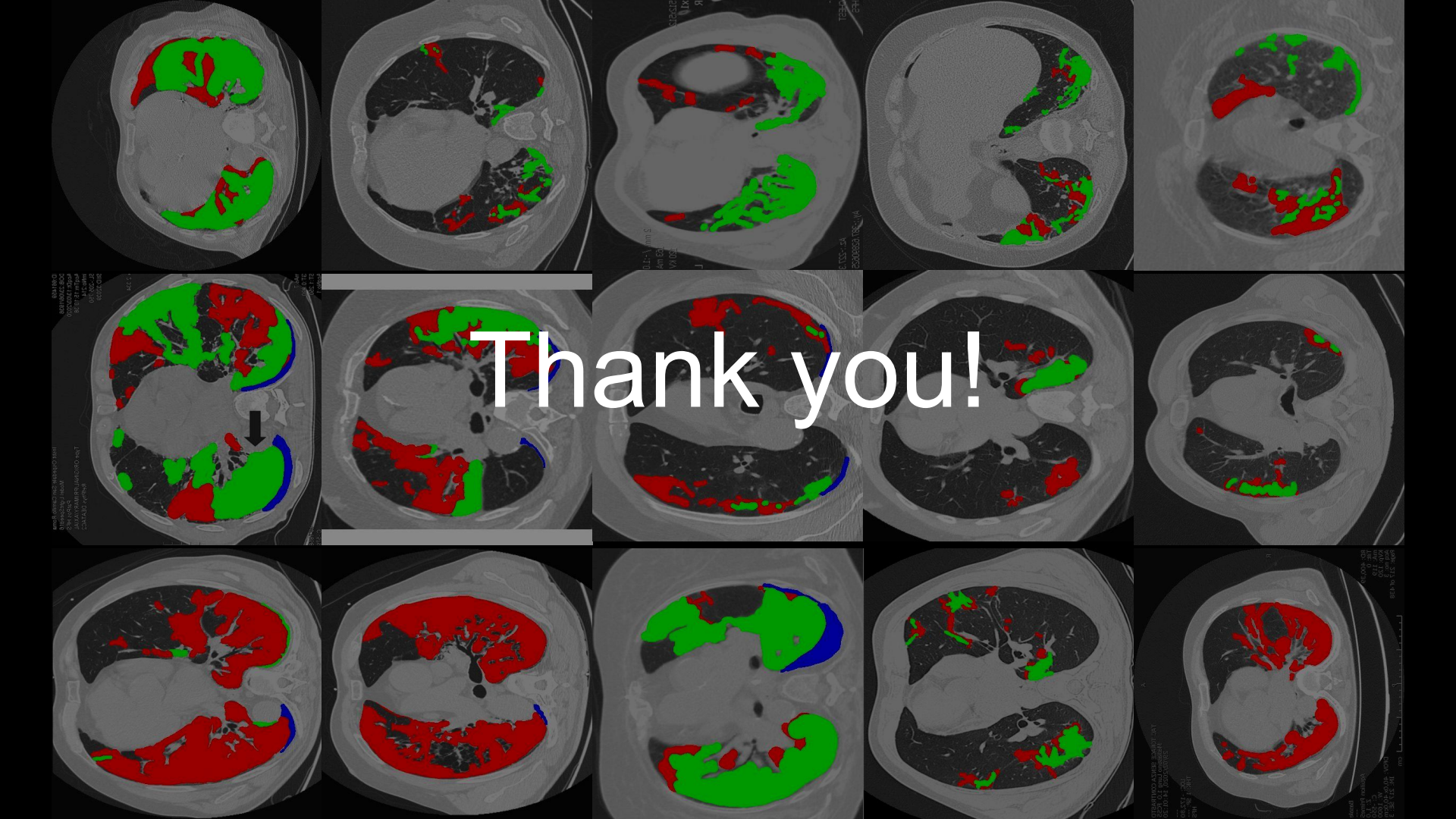
Thank you!