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Machine learning and spatial decomposition for large CT scans

Gary Saavedra
Eric C. Cyr
Sandia National Laboratories

Jacob Schroder
University of New Mexico

Russell Hewett
Virginia Tech

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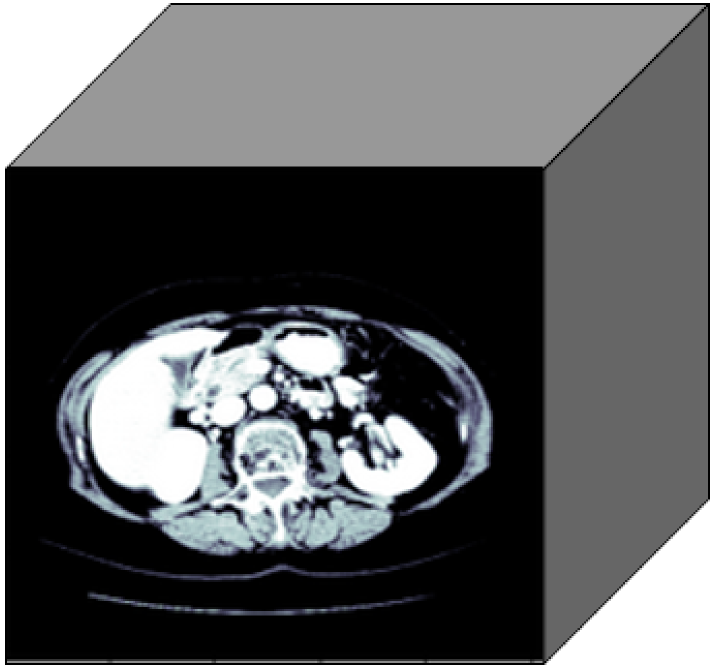
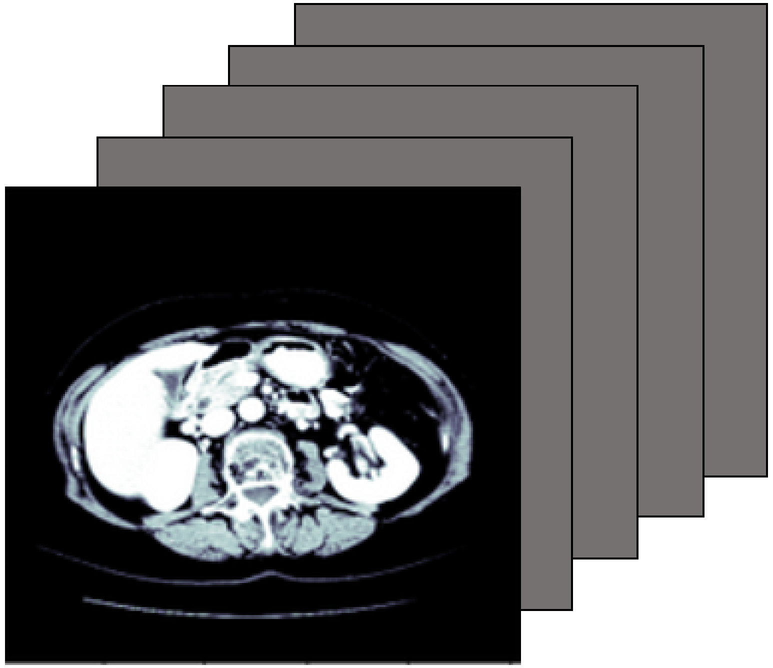
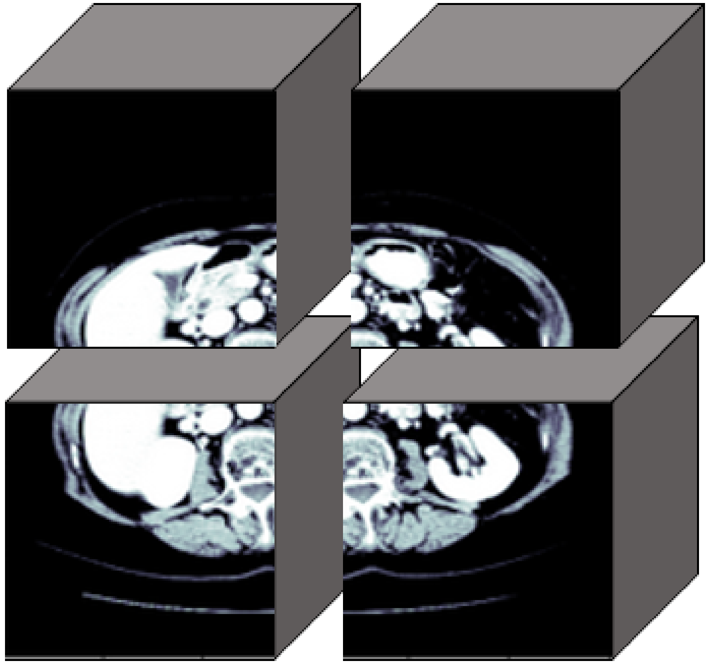
Deep Learning and Spatial Decomposition



Original



2D slices

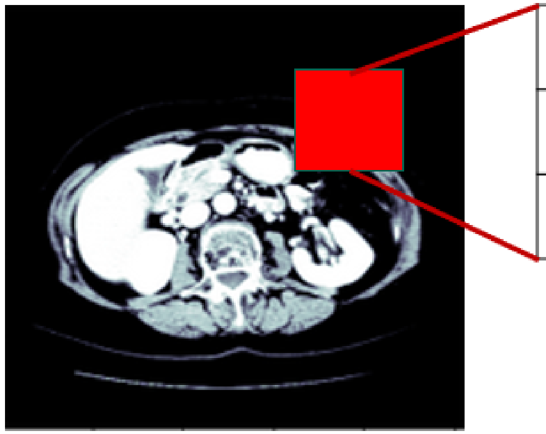


3D decomposition

Spatial decomposition can lead to improvements in both accuracy and speed

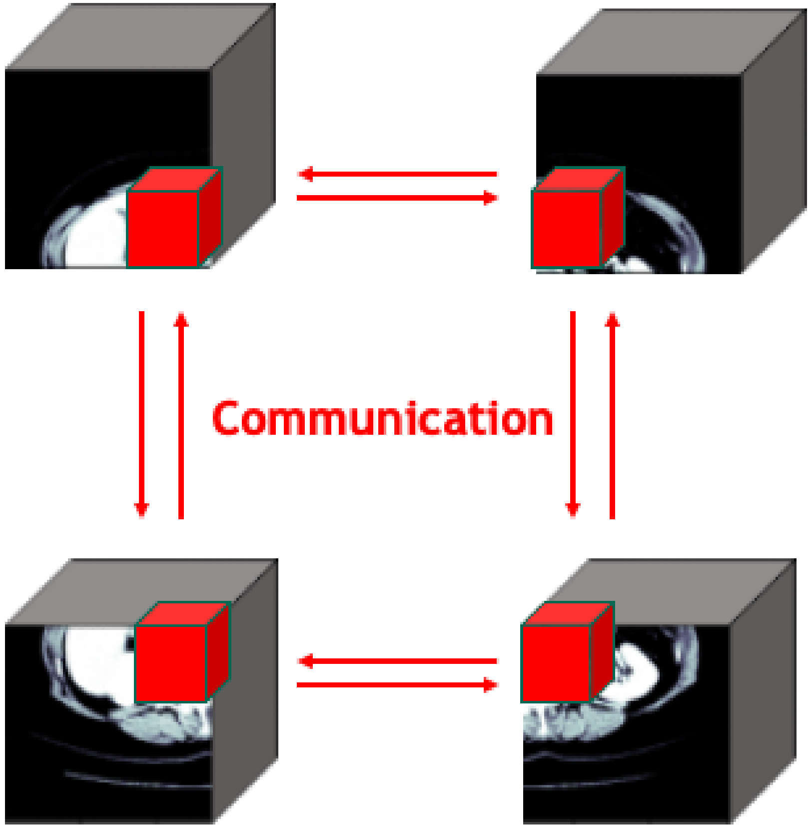
High Resolution Medical Image Analysis with Spatial Partitioning. Hou et al. 2019

How convolution and spatial decomposition works



$$\begin{array}{|c|c|c|} \hline \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \hline \frac{1}{2} & 1 & \frac{1}{2} \\ \hline \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \hline \end{array}$$

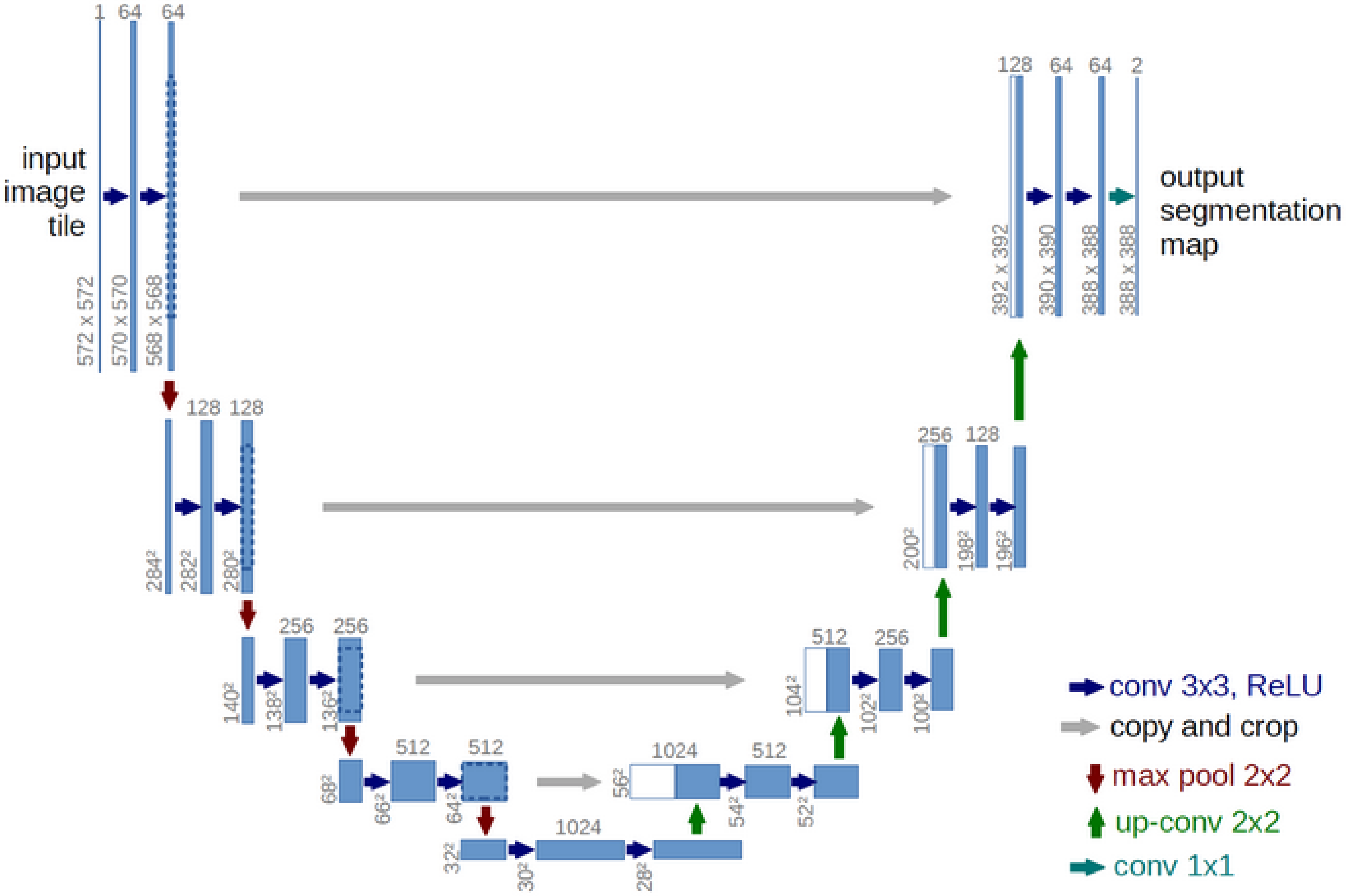
Convolution filter slides over and smooths image



Separate into sub-images and communicate along separation points

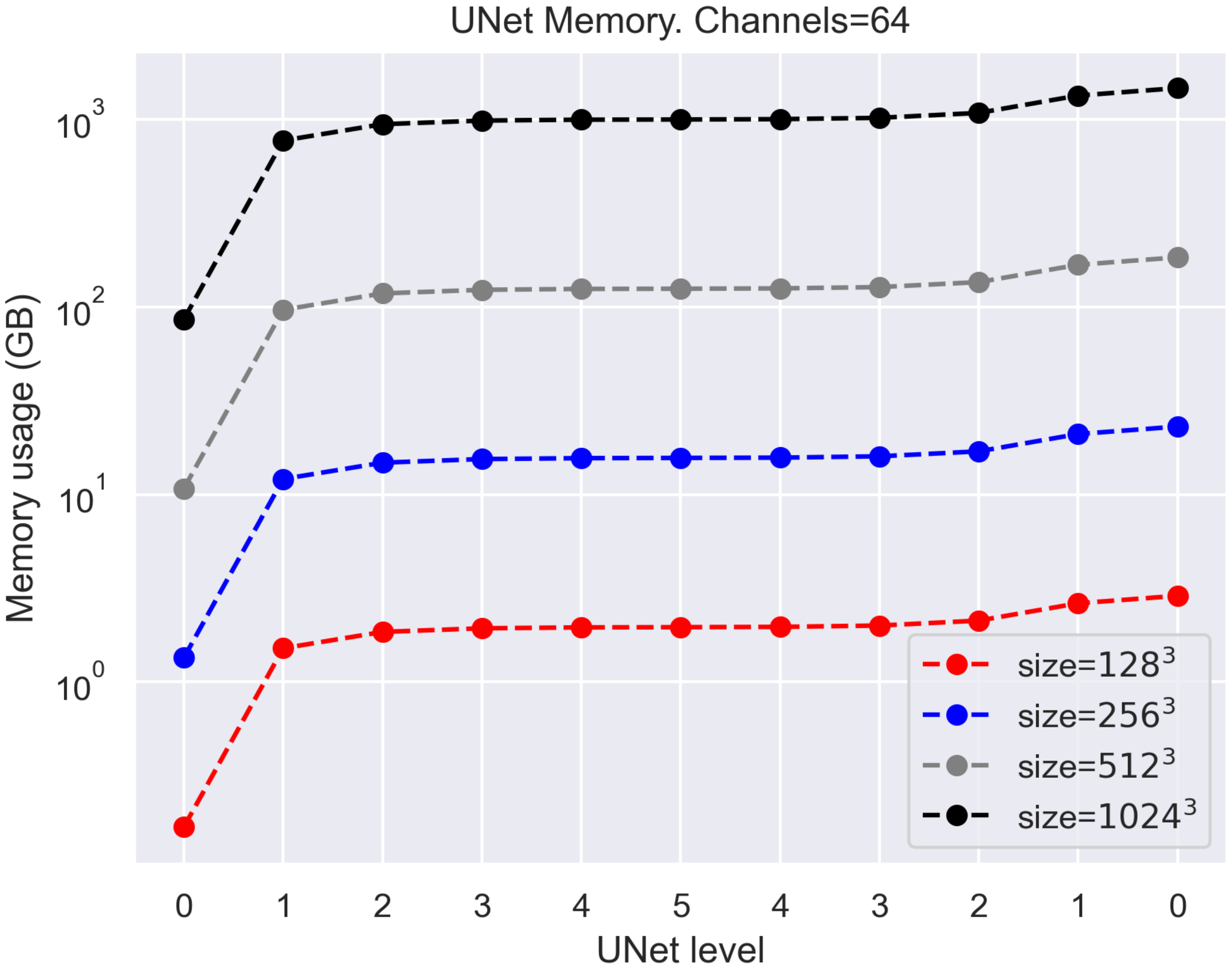
UNet

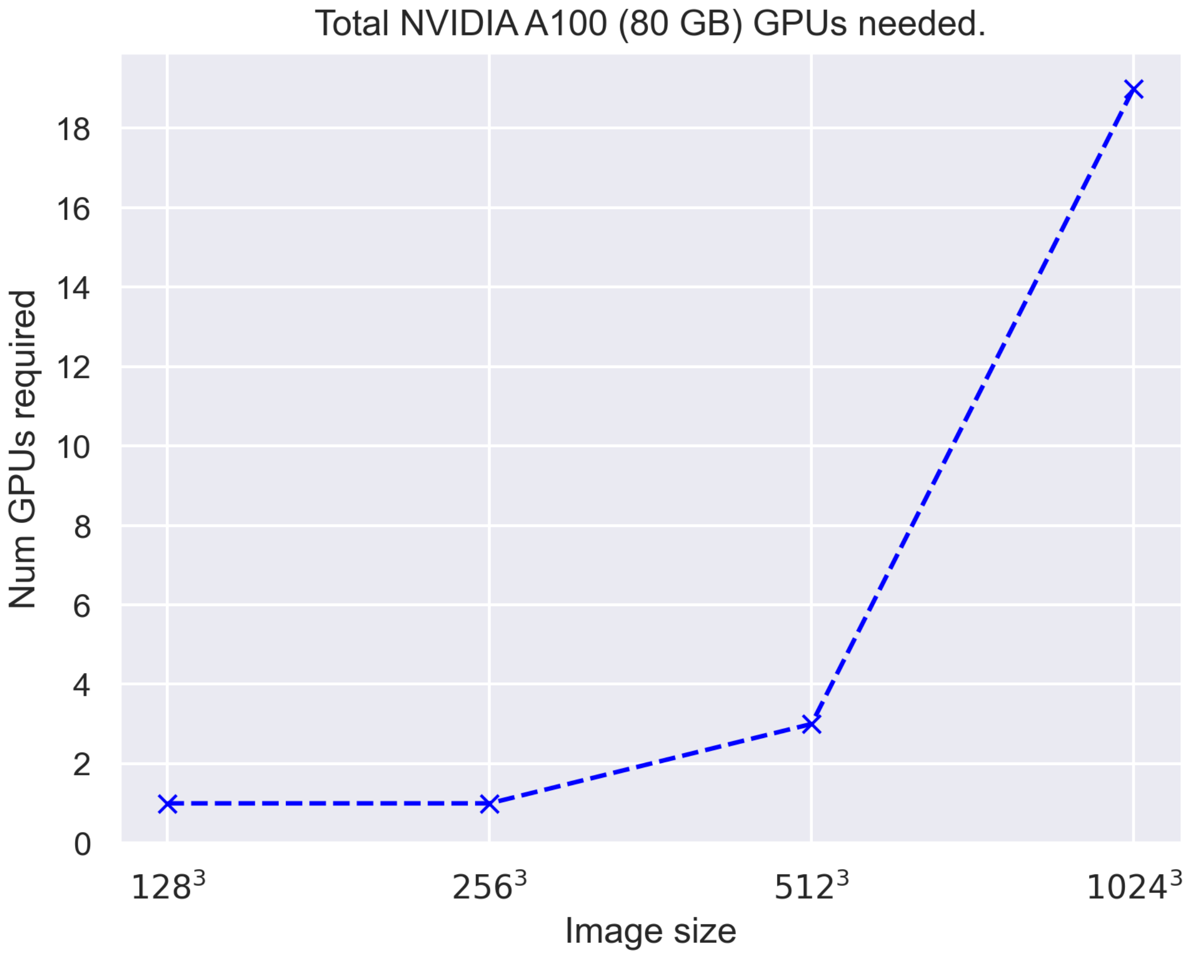
- UNet used for image segmentation
- Works by downsampling and upsampling image through several layers
- Combination of layer and channel requirements can require large amounts of memory



U-Net: Convolutional Networks for Biomedical Image Segmentation. Ronnenberger et al.

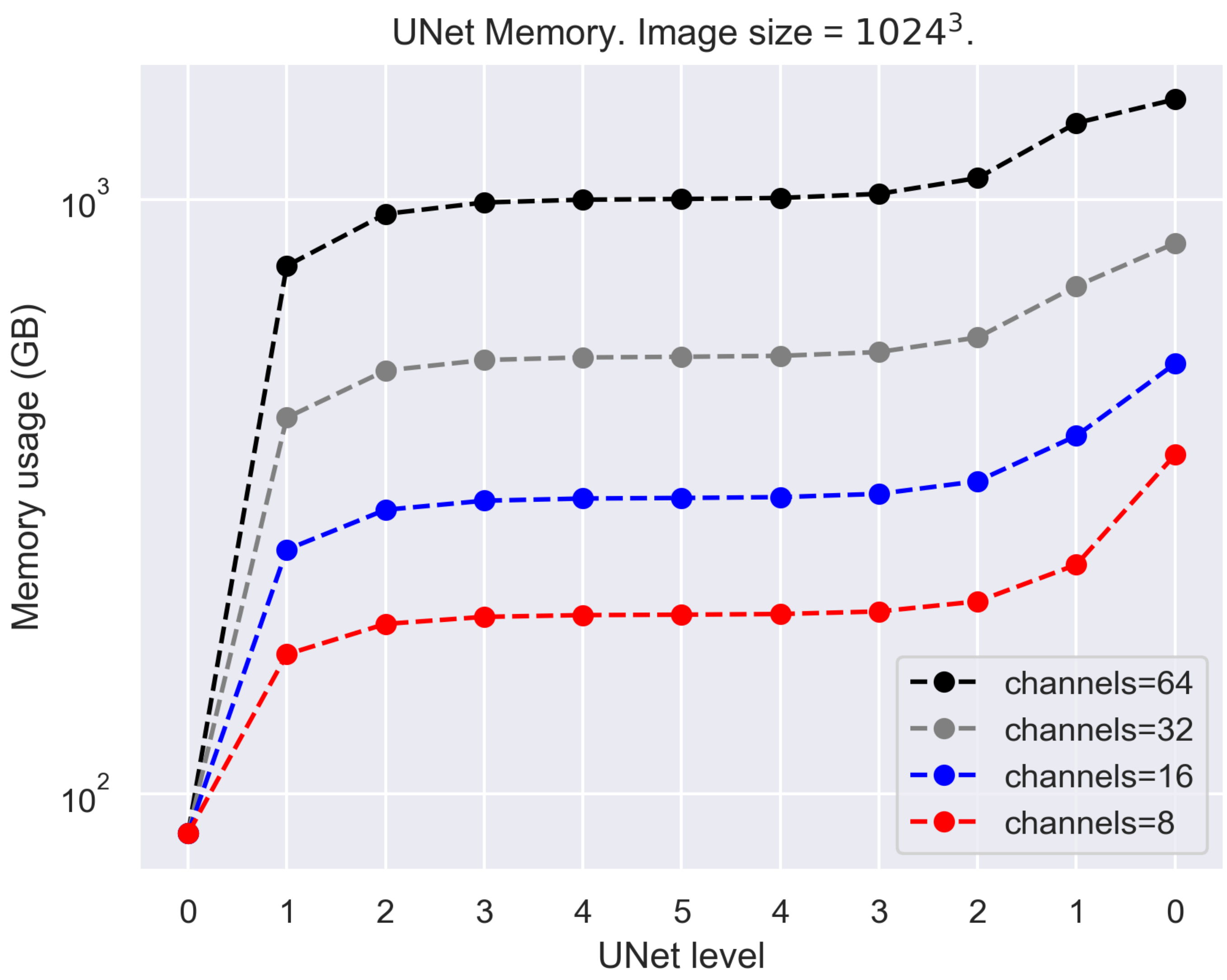
UNet memory growth with respect to image size





Memory requirements become intractable as image size grows

UNet memory growth with respect to channels



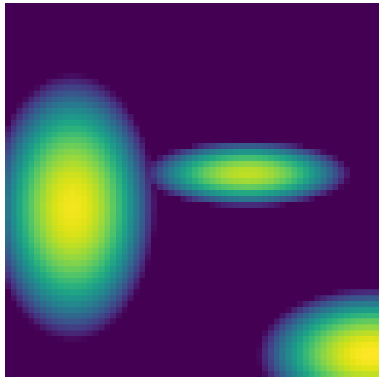
Reducing channels is not enough to overcome high memory usage.

Experimental setup – Ellipse segmentation

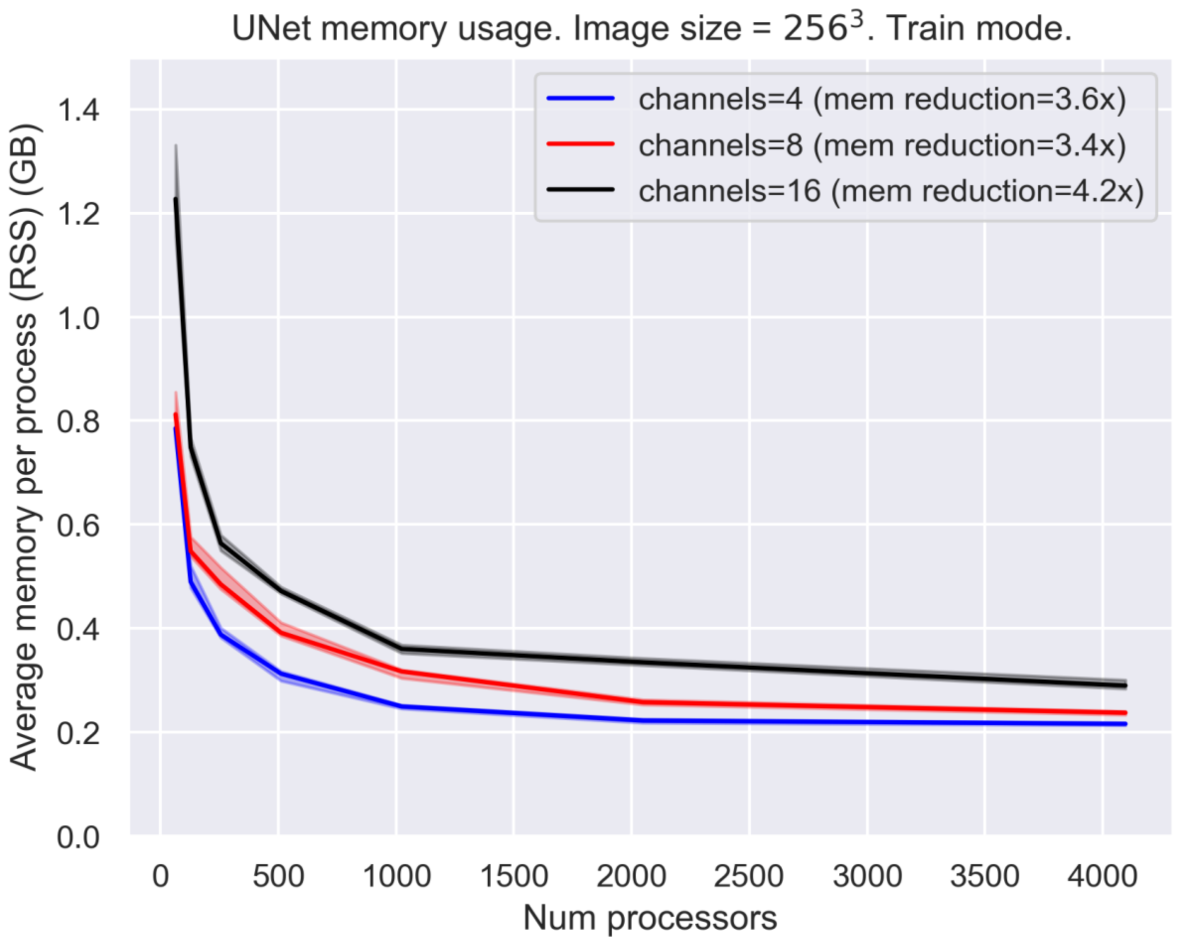
- **DistDL -** spatial parallelism framework

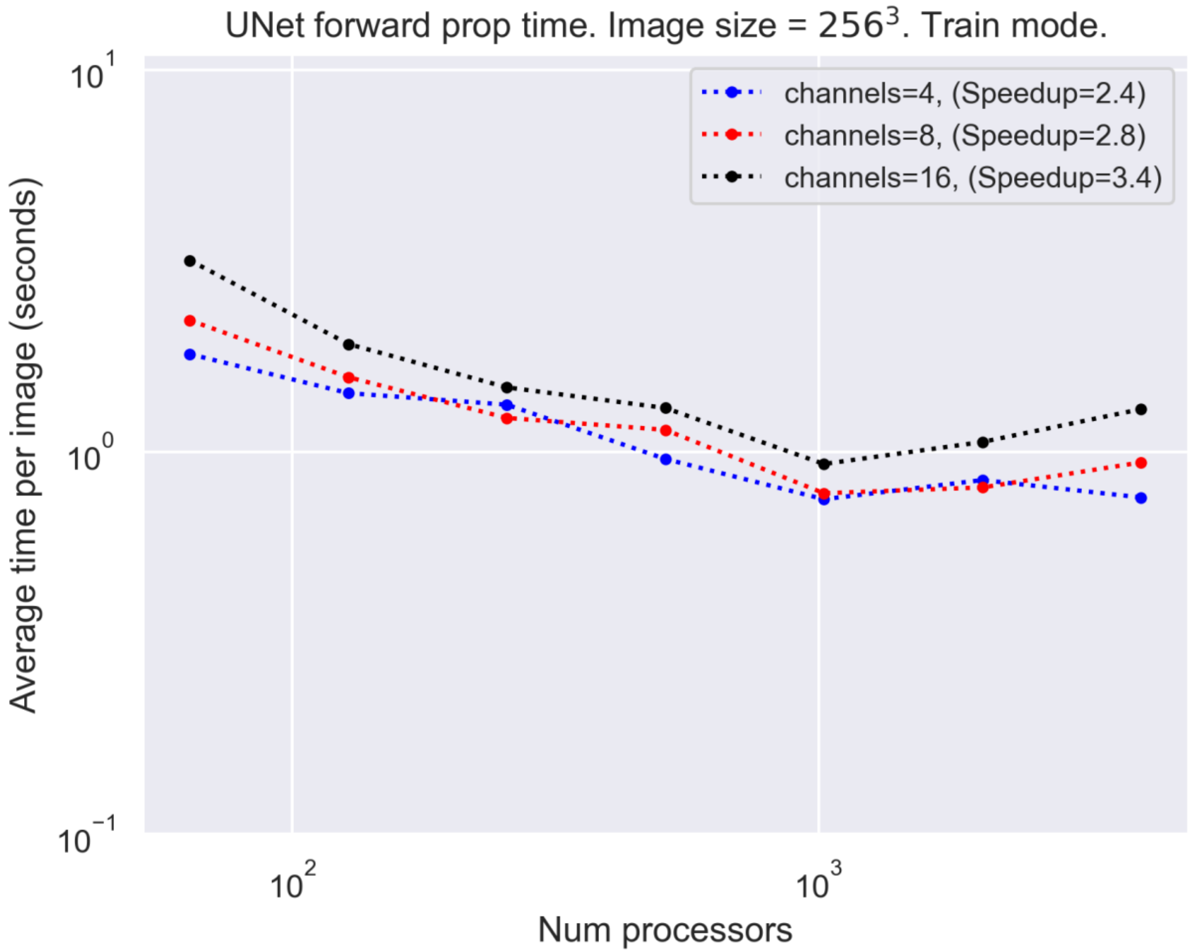
- Architecture
  - Processor - 2.1 GHz Intel Broadwell E5-2695 v4 : 2 sockets : 18 cores
  - RAM per node – 128 GB
  - 1.8 pFlops

- Compute time and memory metrics for ellipse segmentation tasks



Ellipse data results



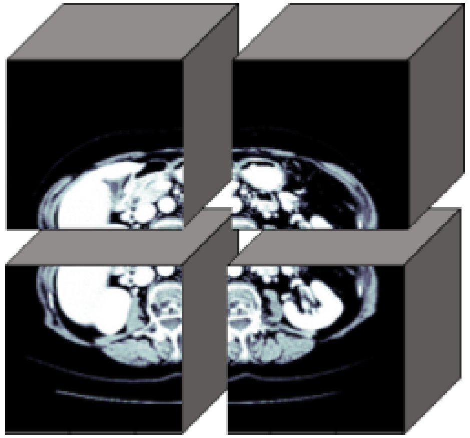


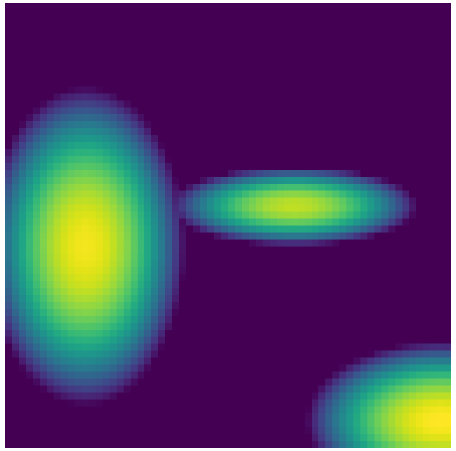
Thousands of processors necessary to handle large memory requirements

Conclusion and Future Work

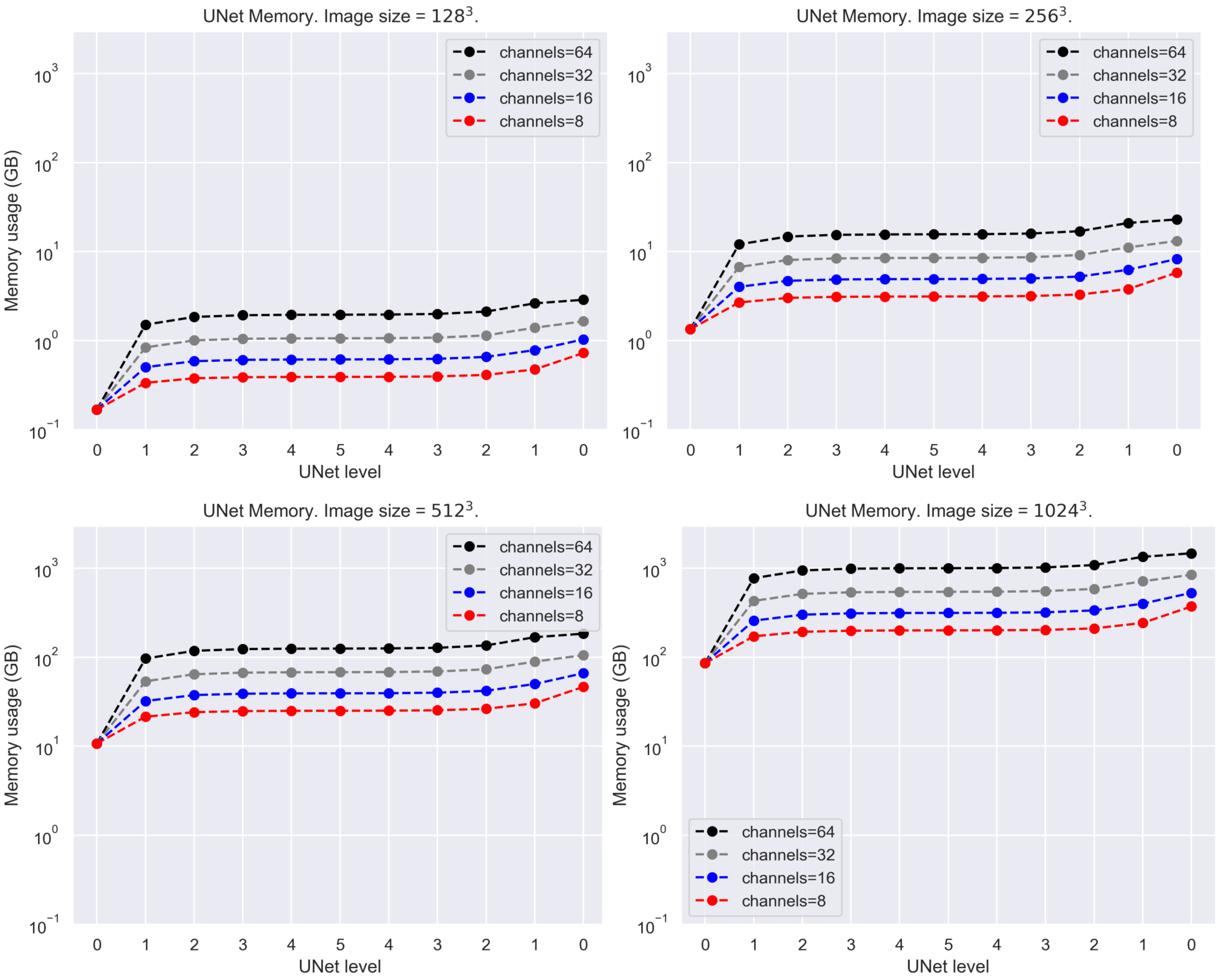
- **Important takeaways**
  - Spatial decomposition is a feasible method for applying ML to large images
  - However, supercomputing environments are likely required
- **Future work**
  - Apply framework to real-world CT scans
  - Can we integrate spatial multigrid for further speedups?

DistDL





Backup Slides



UNet Memory. Image size = 128³.
UNet Memory. Image size = 256³.
UNet Memory. Image size = 512³.
UNet Memory. Image size = 1024³.
channels=64
channels=32
channels=16
channels=8
Memory usage (GB)
UNet level
0 1 2 3 4 5 4 3 2 1 0