

Reaching into the past

Deep learning and historic aerial imagery

Brent Martin, David Pairman, Stella Bellis,
Alexander Amies, Tarek Soliman and Jan Schindler
Manaaki Whenua Landcare Research

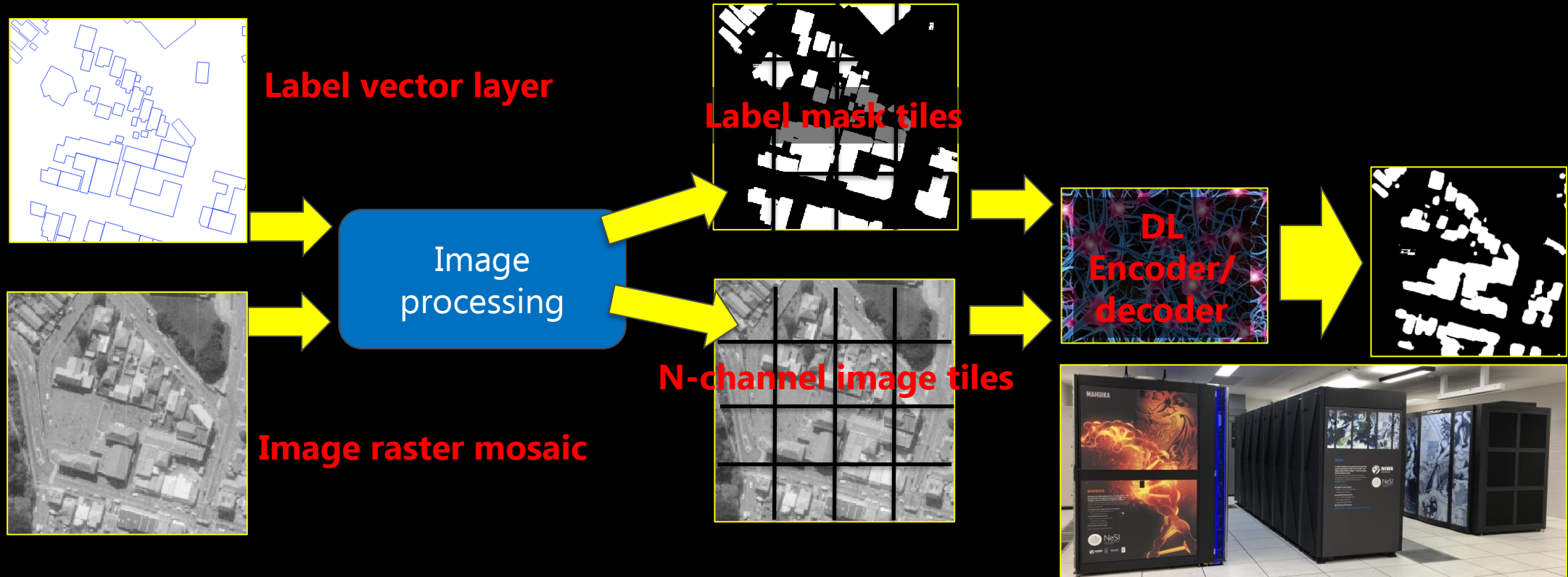
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Goal: map urban built form change over time



Approach: deep learning segmentation



- MWLR pipeline processes input data into image/label mask tile pairs for training/prediction
- Deep learning encoder-decoder network (Unet64) learns to generate mask tiles (512x512 pixels)
- Masks stitched back together (50% overlap)

Training data: LINZ 2016



The screenshot displays the LINZ Data Service interface. On the left, a sidebar lists data types and categories. The main panel shows 71 results for the search term 'buildings'. The results list includes:

- NZ Building Outlines (National Topographic Office)
- NZ Building Outlines (All Sources) (National Topographic Office)
- NZ Building Outlines Lifecycle (National Topographic Office)
- NZ Building Points (Topo, 1:50k) (National Topographic Office)
- NZ Building Polygons (Topo, 1:50k) (National Topographic Office)
- NZ Building Polygons (Topo, 1:250k) (National Topographic Office)

On the right, an aerial map shows a coastal area with numerous blue building outlines overlaid. A legend in the top right corner indicates that the blue outlines represent 'NZ Building Outlines (All Sources)' and 'Wellington 0.3m Rural Aerial Photos (2016-2017)'. The map also shows a search bar and a 'Download or Order' button.

Imagery: 2016 0.3m aerial photos

Labels: NZ building outlines

Historic imagery: Retrolens/LINZ



← → ↻ 🏠 🔒 retrolens.co.nz/map/#/1595774.3358734446/5148637.423989935/1598795.9871479226/5150603.288811196/2193/11

RETROLENS
Historical Image Resource

ableby ? i f t

Support

Map view: Satellite

Map location: Akaroa, Canterbury

Timeline: 1926 — 2022

☒ Auto refresh photos from map.

☐ Place point on the map.

106 images found [add all](#) | [remove all](#) | [download\(0\)](#)

17/01/1941 ☐ add

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ableby

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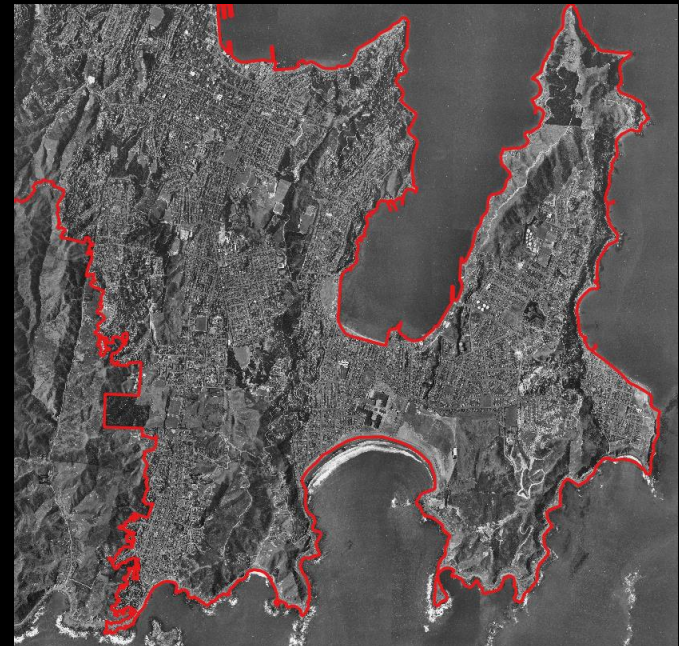
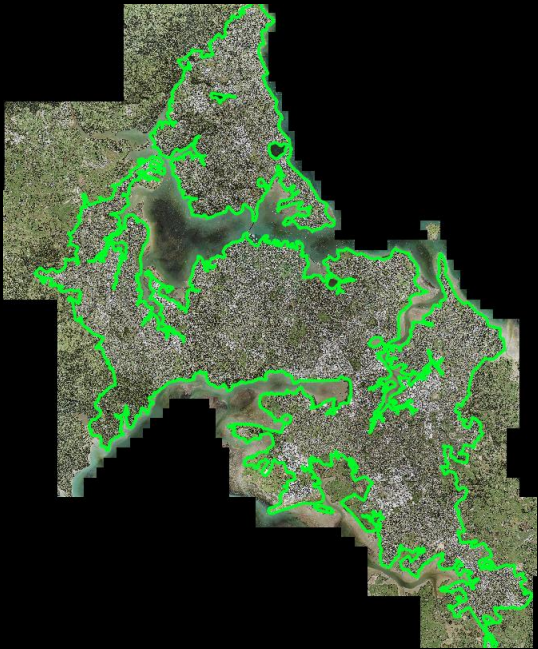
[Developer](#) [Disclaimer](#)

Challenges



How to train the network for all time periods and cities?

- Can a model trained on 2016 be used for historic B&W imagery?
- Can training transfer between cities?



Transfer between time periods



2016: excellent



1940: poor

2016 model fails to transfer to historic imagery

Issue: image quality



2016: digital

Standardised brightness/contrast

Minimal noise

Sharp focus

High spatial accuracy

Shadows

1980: film

Flat contrast

Grainy

Moderate focus

Moderate spatial accuracy

Short shadows

1940: film

Variable brightness/contrast

Grainy

Variable/poor focus

Spatial distortion/displacement

Long shadows

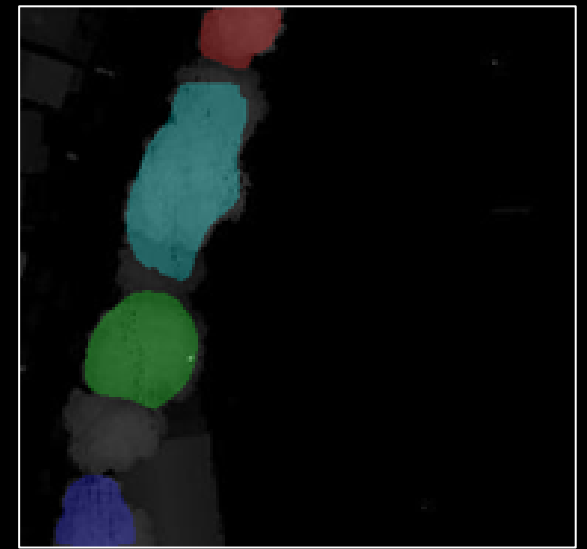
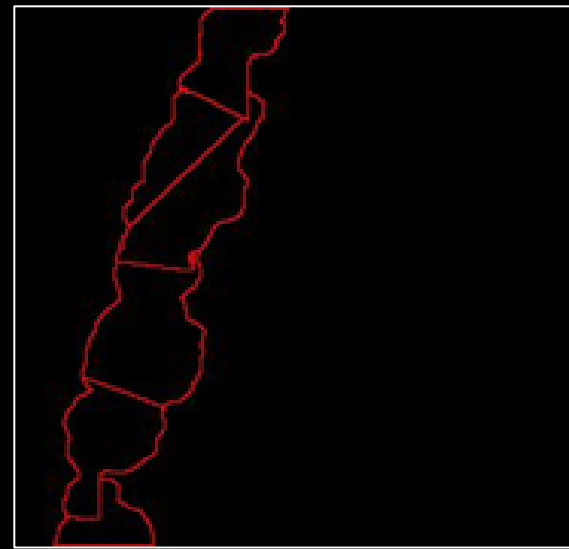
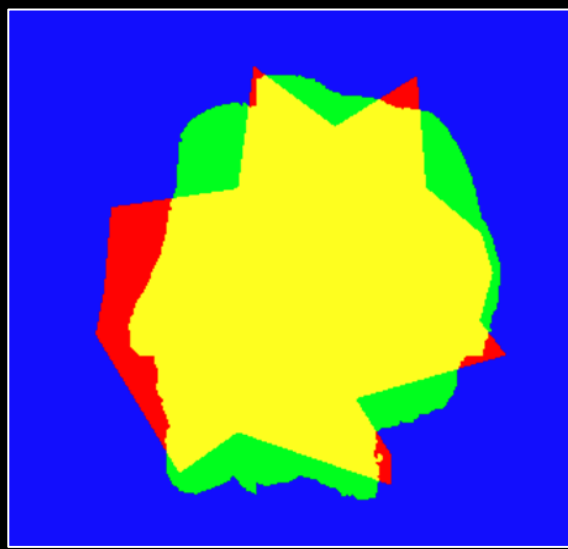
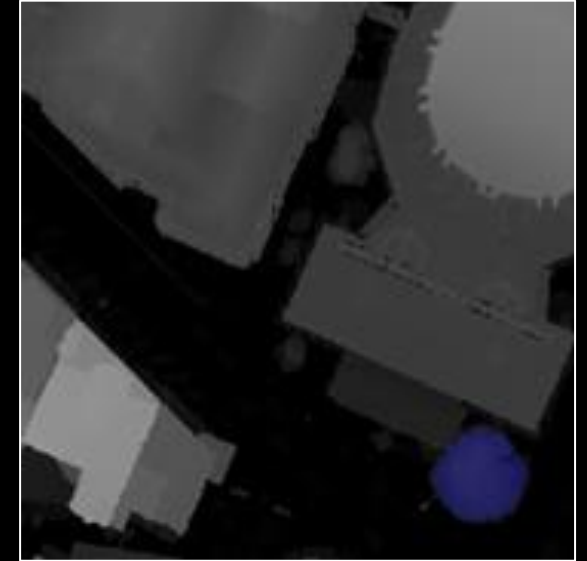
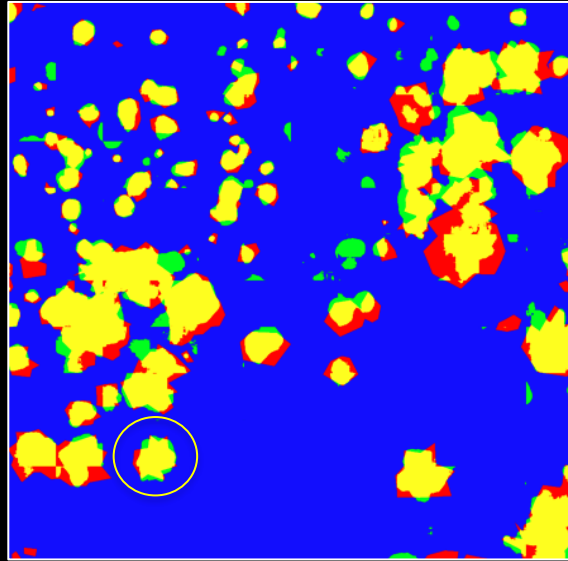
Solution: imperfect learning



- Train model on historic imagery but *current* labels?
 - Buildings may have been built, demolished or modified
 - Image may be displaced because of distortion issues
- Select tiles with “reasonable” match
 - What is “reasonable”?
 - Enough tiles?



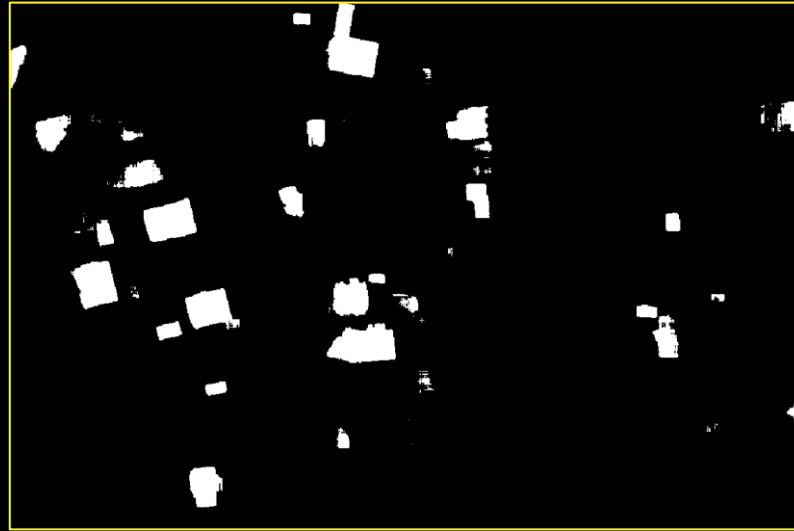
Segmentation label quality tolerance



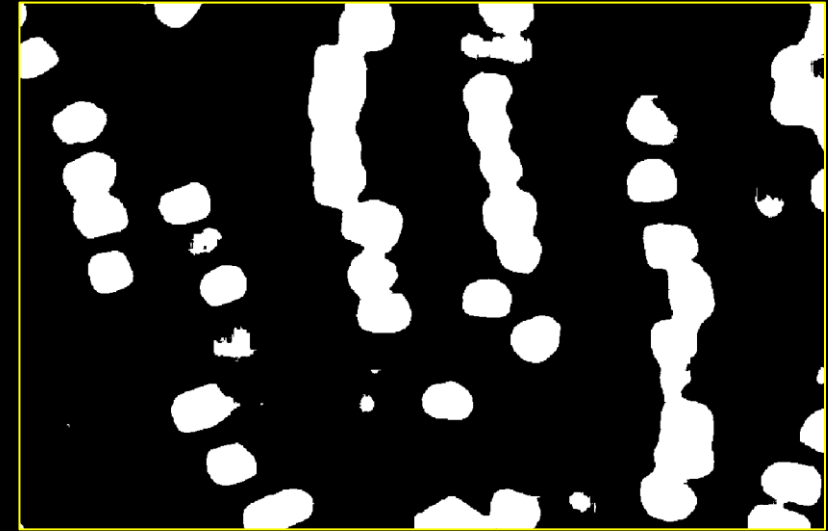
Imperfect training results: 1940



Wellington: 1940 image



2016-based mask



1940 imperfect data mask

Training on 1940s imagery with imperfect data significantly improved

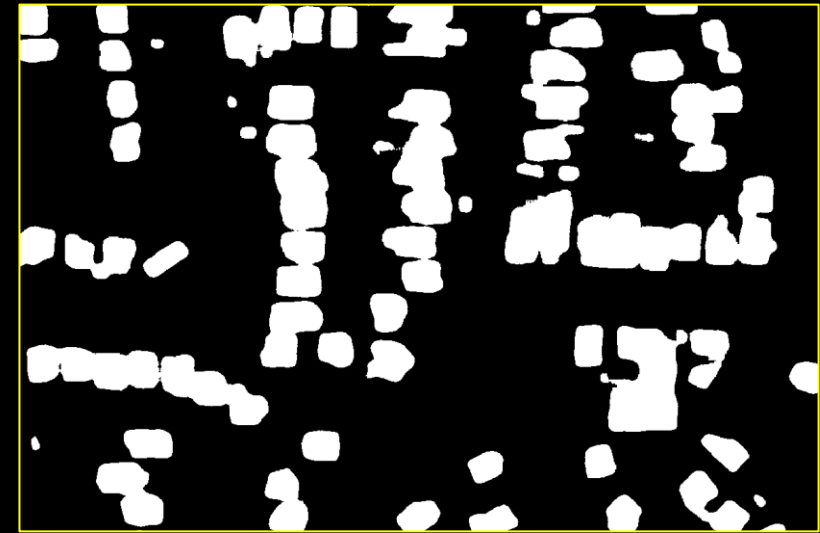
Imperfect training results: 1980



Wellington: 1980 image



2016-based mask



1980 imperfect data mask

1980: significantly improved recall but reduced shape precision

City transfer: Wellington to Auckland



1980



1940



Wellington models transfer well to Auckland

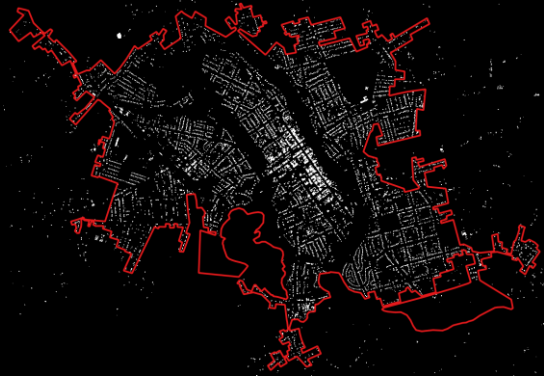


Final model configuration

- Combined model: trains one model on all training data:
 - 2016: all cities
 - 1980: Wellington and Hamilton
 - 1940: Wellington only (insufficient data for Hamilton)

City/year	1940	1980	2016
Wellington	Combined	Wgtn 1980	Wgtn 2016
Auckland	Combined	Wgtn 1980	Auckland 2016
Hamilton	Combined	Combined	Hamilton 2016

Hamilton



1940

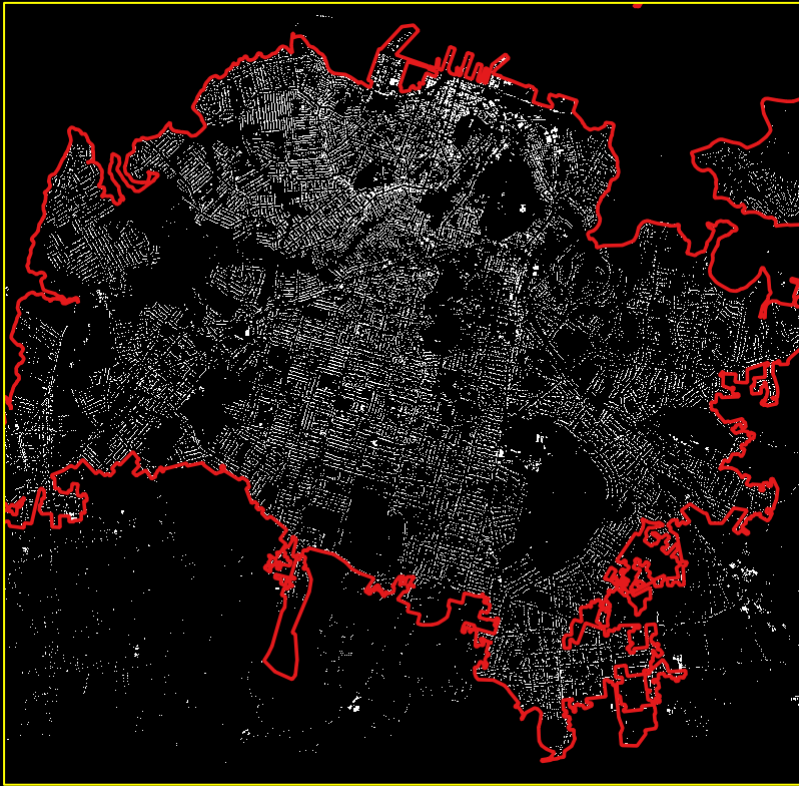


1980

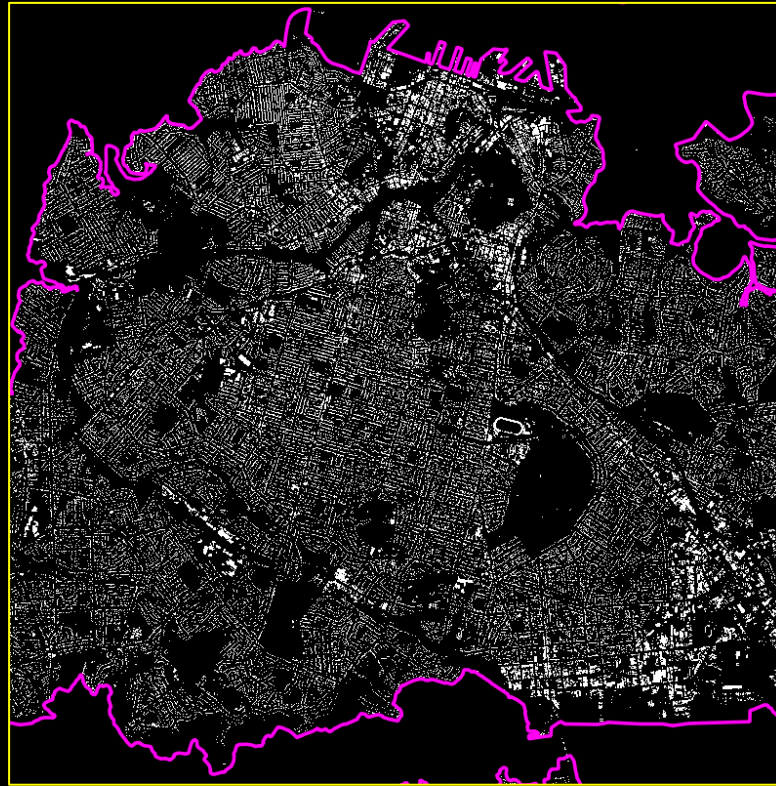


2016

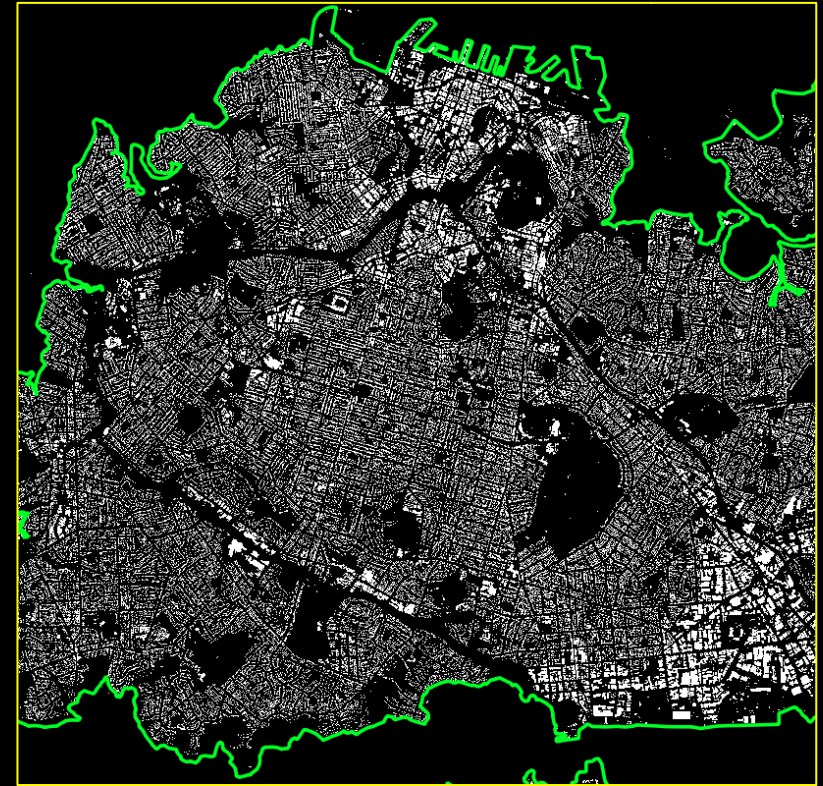
Auckland



1940

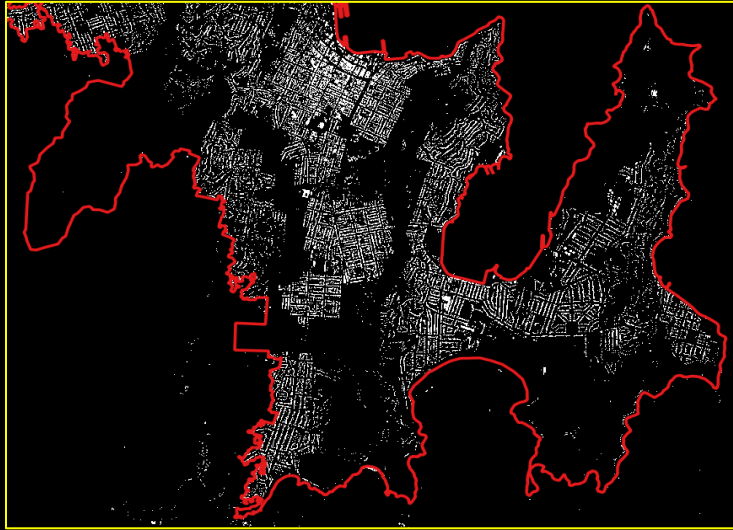


1980



2016

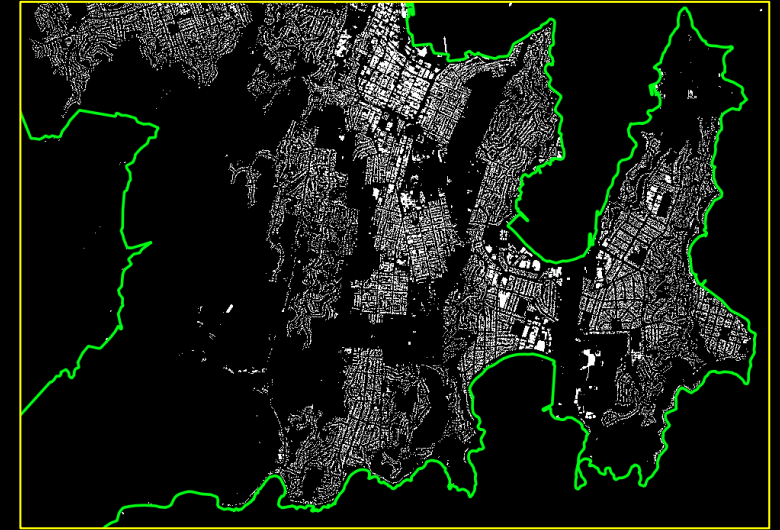
Wellington and Hutt City



1940



1980



2016





Conclusions and further work

- Deep learning can be used to infer buildings from historic imagery
- Historic aerial imagery is challenging because of quality issues
- Models transfer well across cities, less well across time
- Imperfect training labels can yield usable results

Further research:

- Image standardisation
- Improved image registration
- Manual label generation/correction
- Increased training set sizes (e.g. do all of New Zealand)

Questions?