U O W

S9206:
Edge Computing with Jetson TX2 for Monitoring Flows of Pedestrians and Vehicles

Dr J. Barthélemy and Dr N. Verstaevel

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Everyday you are spotted by 75 CCTV!

Cost?

Maintenance

Sydney	$900,000
Melbourne	$400,000
Adelaide	$310,000
Brisbane	$270,000
Toowoomba	$85,000

Really?

Monitoring staff

No one/Record only
Council Staff
Private Security / Council Staff
Private Security Only

WE SEE EVERYTHING

Open-Street CCTV in Australia: A comparative study of establishment and operation (Wilson and Sutton, 2013)

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Agenda

- Who are we?

- Why monitoring traffic using edge-computing?

- The sensor

- First experiments and results

- Conclusion and next steps

At SMART, we believe that People with good information and good tools will make good Decisions and change their world

FLOODING

AGED CARE

ACCESSIBILITY

DIGITAL
LIVING
LAB

TRAFFIC

AIR QUALITY

SAFETY

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Legend
signal strength
strong
medium
LoRaWAN gateways

Brokers Nose

1 0 1 2 3 4 km

Mt Kiera   SBRC

Figtree Reservoir

Farmborough Heights RFS
Cringilla Reservoir

Hill 60

Yallah Reservoir

Mt Warrigal

basemap: Open StreetMap

DIGITAL
LIVING
LAB

NEC

SAFETY COMPASS

ENVIRO
BUILDING SERVICES

BinaryBeer

briometrix

taggle

THE THINGS
NETWORK

wollongong
city of innovation

Peoplecare Love people

irt

BlueScope
STEEL

Transport
Sydney Trains

iag

MESHED

Sydney
WATER

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Do more people live in urban or rural areas?, 1950

Share of the population which live in urban versus rural areas. Here, 'majority urban' indicates more than 50 percent of the population live in urban centres; 'majority rural' indicates less than 50 percent. Urban populations are defined based on the definition of urban areas by national statistical offices. This is based on estimates to 2016, combined with UN projections to 2050.
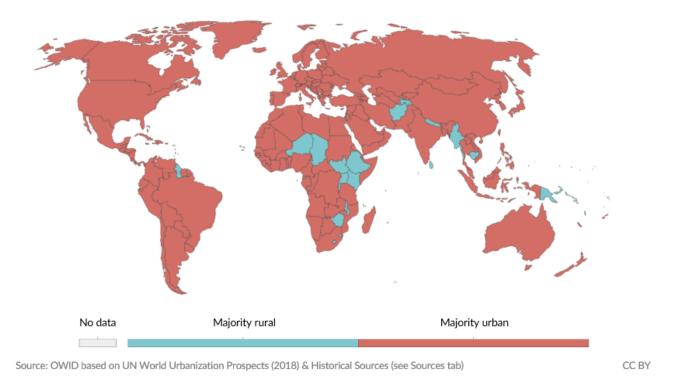
No data   Majority rural   Majority urban

Source: OWID based on UN World Urbanization Prospects (2018) & Historical Sources (see Sources tab)

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Do more people live in urban or rural areas?, 2050

Share of the population which live in urban versus rural areas. Here, 'majority urban' indicates more than 50 percent of the population live in urban centres; 'majority rural' indicates less than 50 percent. Urban populations are defined based on the definition of urban areas by national statistical offices. This is based on estimates to 2016, combined with UN projections to 2050.

No data   Majority rural   Majority urban

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Traffic in 1960

Title: George Street looking north, Sydney

Date: c. 01/01/1960

Digital ID: 17420_a014_a0140001213

Rights: No known copyright restrictions

https://www.records.nsw.gov.au/image/17420_a014_a0140001213

Traffic in 2013

Description	Southbound traffic congestion on George St, Sydney
Date	23 June 2013, 17:26:45
Source	A crop of George Street-1.jpg
Author	Sardaka

https://upload.wikimedia.org/wikipedia/commons/0/05/George_Street_congestion_during_evening_peak_hour_2013.jpg

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68% of the world population projected to live in urban areas by 2050

9 in 10 breathe polluted air

Air pollution causes **1** in 9 death worldwide

Smart Cities, Smart Liverpool, Smart Pedestrian Project

The case of Liverpool

+/- 30,000 inhabitants

The case of Liverpool

CBD is growing fast: UoW campus, airport,... ➡️ **+30k commuters**

⇒ **What does it mean for the city and its community?**

⇒ **Smart Cities and Suburbs Program: How can IoT inform the city?**

Community engagement

arki_lab

SMART LIVERPOOL
Smart Cities, Smart Liverpool, Smart Pedestrians

A Report By arki_lab
A Collaboration Between arki_lab smart UNIVERSITY OF WOLLONGONG LIVERPOOL CITY COUNCIL

Playing the game– Afternoon session @Emily Tinson

Inspiration wall @Emily Tinson

Presentation– Afternoon session @Emily Tinson

Discussion– Afternoon session

Playing the game– Evening session

The game board

https://www.arkilab.dk/

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GROWTH

INADEQUATE SPORTS CENTRES

PEDESTRIAN FLOW

BIGGER PARKS

CULTURAL DIVERSITY

MIXED USED CBD TRAFFIC SENSE OF COMMUNITY

GRID SYSTEM PERCEPTION AND IMAGE

LACK OF PARKING WALKABILITY

DIVERSITY OF FOOD

LACK OF NIGHT ABANDONED SHOPS

LIVERPOOL HOSPITAL HERITAGE

This map shows different access points identified by the participants as well functioning or problematic. Most of the locations shown on the map were mentioned several times in different groups. However, they're shown only once on this map.

Well-functioning access points

Problematic access points

The yellow dots indicate the approximate location of the sensors and the size of the dots represent the number of groups who have suggested that particular location.

Results from the workshop

Issues

- **Traffic** and lack of parking space as major problem
- **Not cycle-friendly**
- CBD suffers from lot of **car traffic and noise**

Desirable solution

- **Real time multi-modal** detection and tracking
- **Privacy** compliant
- **Interoperable and scalable**
- **Leveraging** existing infrastructures

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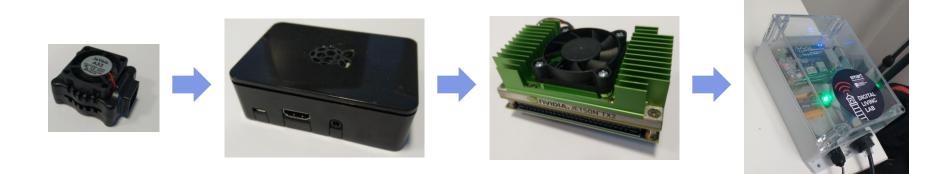
How about using CCTV?

➡️ **Privacy!**

History of the prototypes

+ open source software

The sensor

An edge computing device
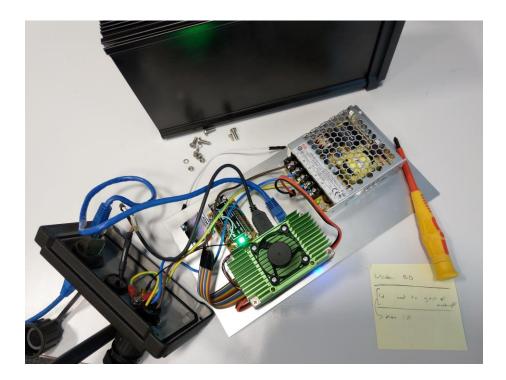
Components

— NVIDIA Jetson TX2 for onboard processing

— Pycom LoPy 4 for data transmission on The Things Network

— Camera (USB webcam / existing CCTV)

The sensor

Actual state…

The sensor

Configuration

The sensor: Deployment

LoRaWAN Rack version

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The sensor: Deployment

3U Rack version for oneM2M

From the input to the dashboard

Image Acquisition
- CCTV/Webcam

Detection
- YOLO V3

Tracking
- SORT

Data transmission
- LoRaWAN/oneM2M

Database + Dashboard
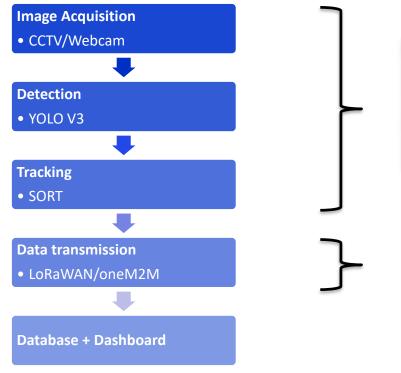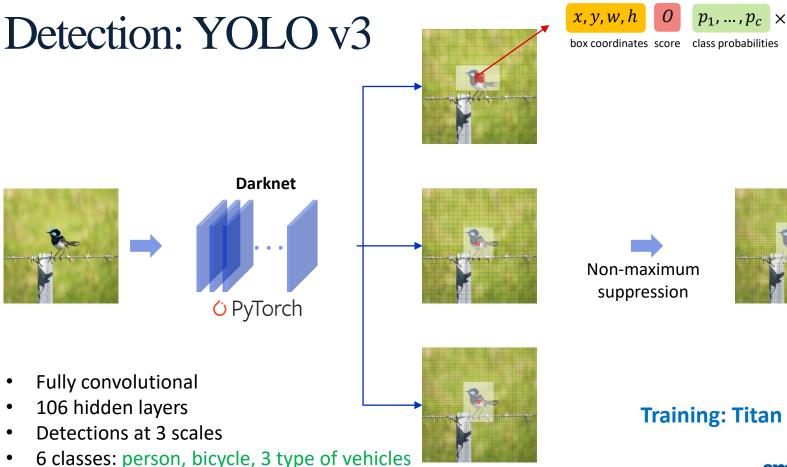
Image credit: NVIDIA Corporation

Image credit: Pycom

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Detection: YOLO v3

Darknet

○ PyTorch

x, y, w, h — box coordinates
O — score
$p_1, ..., p_c$ — class probabilities
$\times K$ — #boxes predicted/cell

Non-maximum suppression

Training: Titan V

- Fully convolutional
- 106 hidden layers
- Detections at 3 scales
- 6 classes: person, bicycle, 3 type of vehicles

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Detection: YOLO v3

YOLO v3 performances
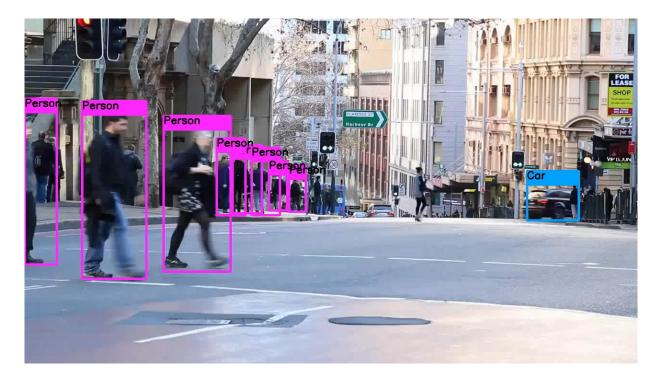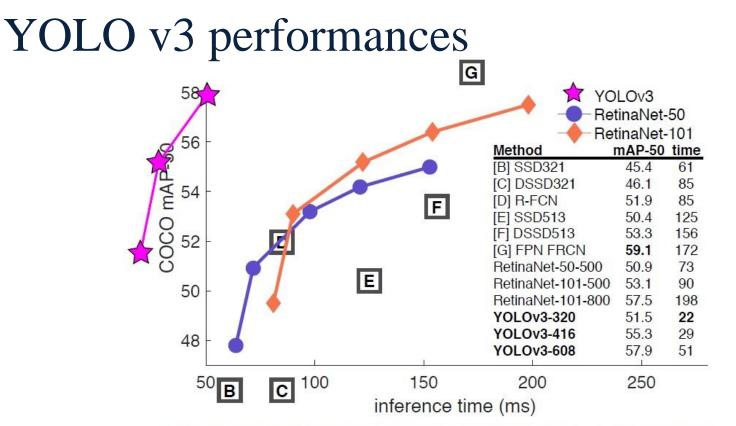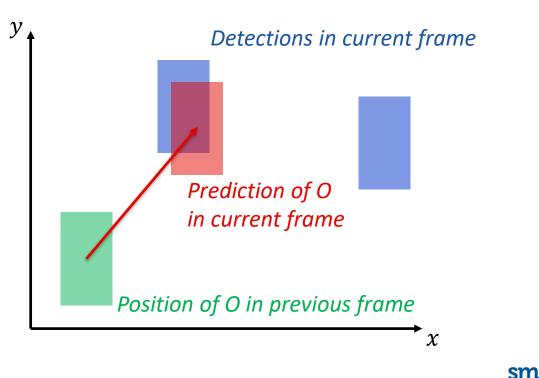
Figure 3. Again adapted from the [7], this time displaying speed/accuracy tradeoff on the mAP at .5 IOU metric. You can tell YOLOv3 is good because it's very high and far to the left. Can you cite your own paper? Guess who's going to try, this guy → [14].

Image credit: Redmon, J. and Farhadi, A. (2018). YOLOv3: An Incremental Improvement

Multi-object Tracking: SORT

- Kalman filtering
- Hungarian Algorithm
- IoU

Detections in current frame

Prediction of O in current frame

Position of O in previous frame
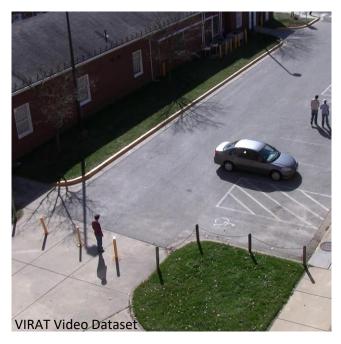
Detection: YOLO v3

- **Detecting locations of pedestrians and vehicles**

- **Number of objects of each type**

VIRAT Video Dataset

Tracking: Kalman Filtering

- **Associating IDs with the detections**

- **Trajectories**

VIRAT Video Dataset

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```
{'285': ['person', 435.7089532230427, 158.81767115171266, 712.3995574660166, 626.14454559095]}
FPS of the video is  4.19
Adding 285 to data
{'285': ['person', 437.7352621210605, 156.43164047212613, 714.6494187096064, 629.1544345549298]}
FPS of the video is  4.13
```

No image ➡ **Privacy OK!**

Liverpool Smart Pedestrian architecture

Sensors   **Transport**   **IoT Core**   **Applications**

Citizens app

Dashboard

Analytics

Modelling

Agnosticity

LoRaWAN™

OM2M Eclipse

- **Open source** service platform for M2M interoperability based on the oneM2M standard.

- Follows a **RESTful** approach GET/POST/DELETE/SUBSCRIBE

- **Access control policies**

- Plugins

- Can be **decentralised** with multiple nodes

- Support different technologies:
    - Lora
    - Zigbee
    - Sigfox
    - Bluetooth Low Energy
    - Z-wave
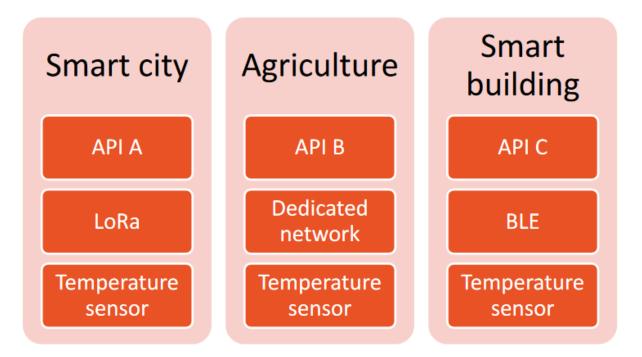
From vertical integration…
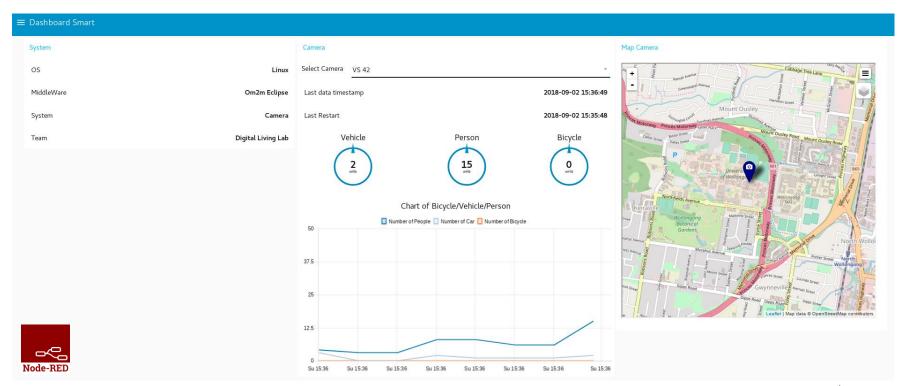
… to horizontal integration

Smart city	Agriculture	Smart building
API		
Networks		
Things		

Dashboard

Dashboard
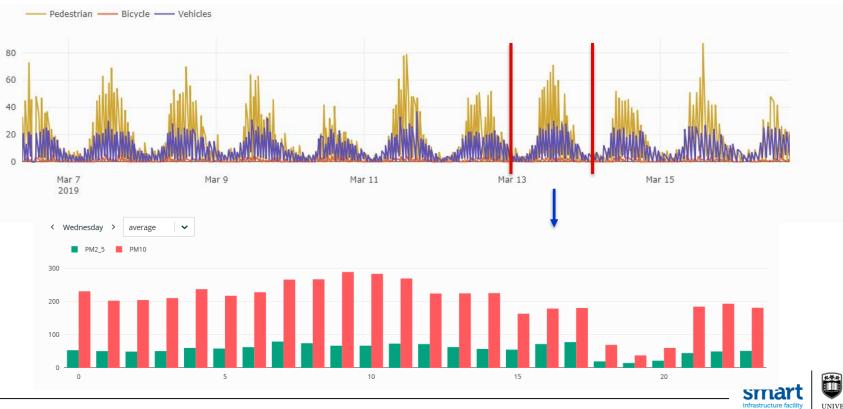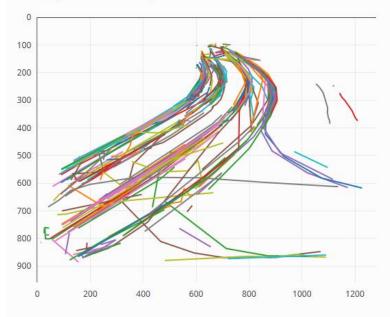
Dashboard: air quality vs traffic
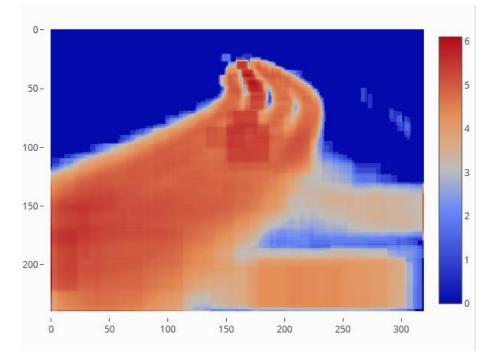
Dashboard: trajectories and heatmaps
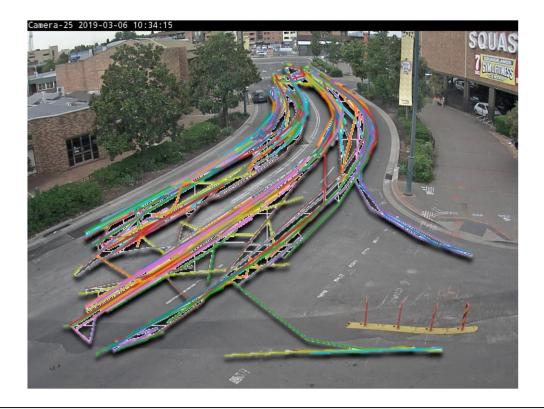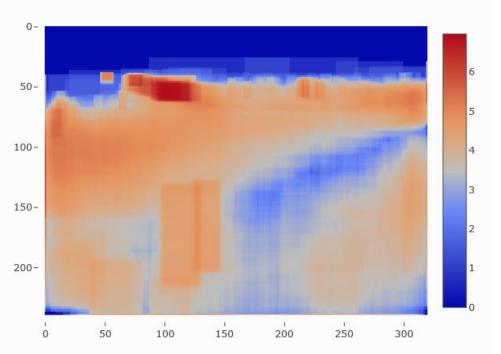
Dashboard: data into context

Dashboard
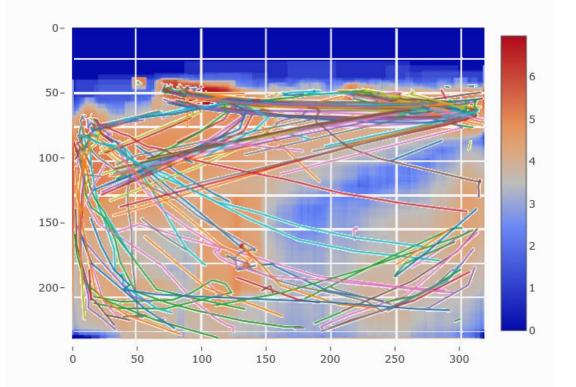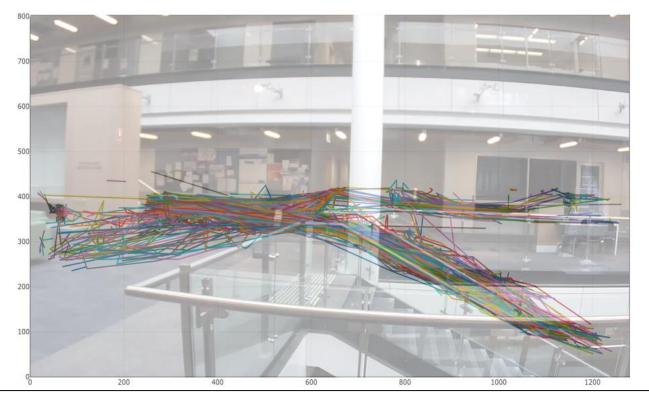
Dashboard: trajectories on heatmap

Dashboard
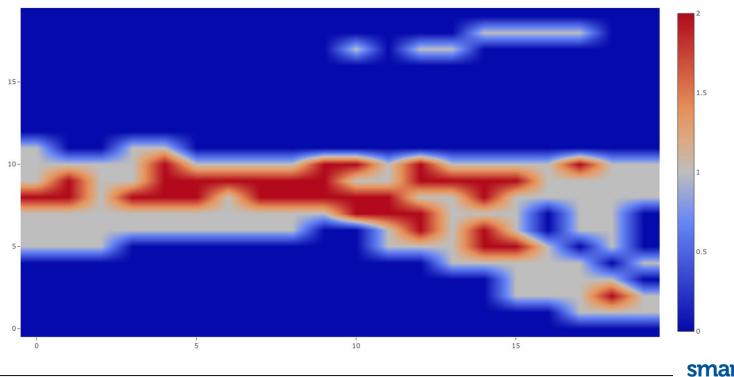
Trajectories of the detections (inside a building)

Dashboard

Heatmap of the maximum number of the detections (inside a building)

Dashboard

Next steps: Inferring network dynamics
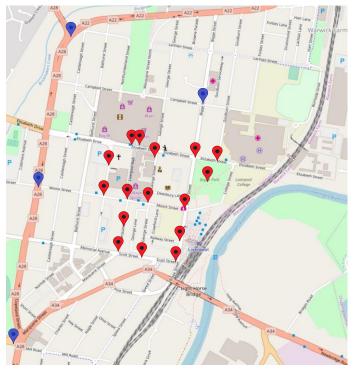
Image credit: OpenStreetMap
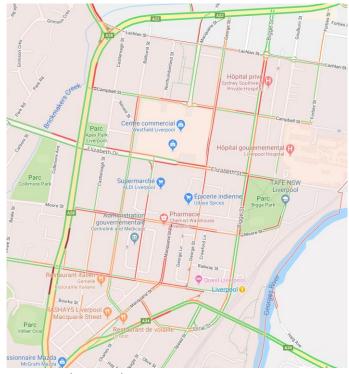
Image credit: Google Maps

Next steps: Algorithm transferability

Testing in Vietnam

Next steps

Improving training dataset
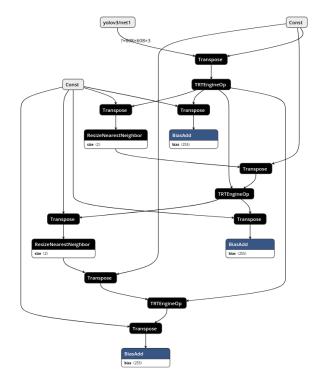

data augmentation

Next steps: Jetson AGX Xavier + TensorRT

Image credit: NVIDIA Corporation
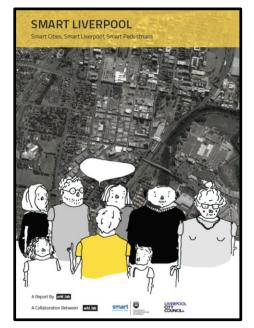
Preliminary tests: 100% increase in performance

Conclusions

It's only the beginning!

| Citizens app | Dashboard | Analytics | Modelling |

- **Jetson TX2 for real time object detection and tracking**

- **Privacy compliant... but meaningful information**

- **Open data for people centric approach**
  - citizen applications
  - city and traffic planners

- **IoT core scalable and interoperable**
  - adding new sensors: air quality, noise, ...

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Smart Cities, Smart Liverpool, Smart Pedestrians

A Report By arki_lab

A Collaboration Between arki_lab smart LIVERPOOL CITY COUNCIL

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But it's already successful!

Best Local Government Initiative
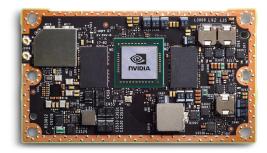
An ecosystem around the Jetson TX2

Keep In Touch

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🌐 smart.uow.edu.au

▶ SMART Infrastructure Facility

🐦 @SMART_Facility

in linkedin.com/company/smart-infrastructure-facility-university-of-wollongong
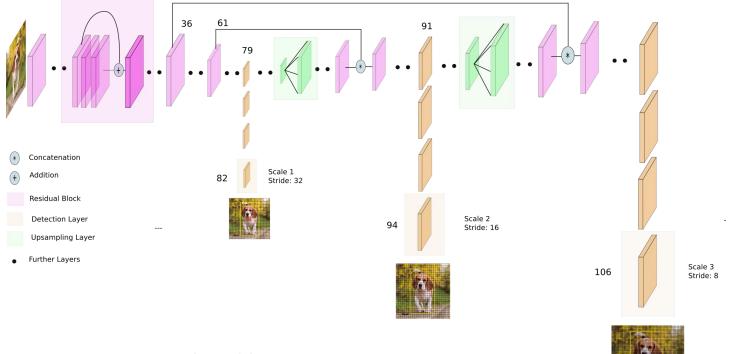
Ⓦ uowblogs.com/smartinfrastructure

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YOLO v3 architecture

YOLO v3 network Architecture

Detection: YOLO v3

Training: Titan V

- Fully convolutional DNN
- 106 hidden layers
- Detections at 3 scales
- 3 classes: person, bicycle, vehicles

PyTorch + NVIDIA CUDA cuDNN + FP16

Inference: Jetson TX2

t_x, t_y, t_w, t_h

Box coordinates

p_0

Score

$p_1, p_2, p_3 \times B$

Class scores

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