1. What is wrong with scats volume, can it be machine learned ‘fixed’ or not?
2. Hierarchy of events leading to SCATS “volume calculations” VO, VK, DS.
3. Synthesis: SCATS hierarchical (pyramid) accuracy depends on faultless loop detector operation
4. What research exists into loop detector failure, and what frequency of failure exists?
5. Is there a World recognized body, who can authoritatively assert failure rates for loop detectors?
6. Does VicRoads have any technology to detect loop failure, if yes, what is the level and continuity of failure?
7. How does the 25% across the United States of America at an estimated 25% constant failure rate, compare to VicRoads today ?
8. Is loop detector failure, measured by DS (degree of saturation) the only data issue created by reliance on loop detectors?
9. Ought Computer Vision, overcome, replace, correct what we know about ‘SCATS volume errors’?
10. Is a one method approach for Computer Vision proposed, as the best solution?
11. Where to next, what are the next steps?

* What is wrong with SCATS volume, can it be machine learned ‘fixed’ or not? ***(Past)***
* How can computer vision, overcome, replace and correct what we know about ‘SCATS volume errors’? ***(Present)***
* Where to next, what are the next steps? ***(Future)***

Why hasn’t this happened.

This is well covered here, **Finance and Economics:** <http://kimoon.co.kr/gmi/reading/friedman-1966.pdf>

Positive science and normative science – or better said, unbiased observations and unbiased observations made bias – are the issue at hand.  
  
*“Viewed as a body of substantive hypotheses, theory is to be judged by its predictive power for the class of phenomena which it is intended to "explain." Only factual evidence can show whether it is "right" or "wrong" or, better, tentatively "accepted" as valid or "rejected." As I shall argue at greater length below, the only relevant test of the validity of a hypothesis is comparison of its predictions with experience. The hypothesis is rejected if its predictions are contradicted ("frequently" or more often than predictions from an alternative hypothesis); it is accepted if its predictions are not contradicted; great confidence is attached to it if it has survived many opportunities for contradiction. Factual evidence can never "prove" a hypothesis; it can only fail to disprove it, which is what we generally mean when we say, somewhat inexactly, that the hypothesis has been "confirmed" by experience.*

*…*

*Truly important and significant hypotheses will be found to have "assumptions" that are wildly inaccurate descriptive representations of reality, and, in general, the more significant the theory, the more unrealistic the assumptions (in this sense).12 The reason is simple. A hypothesis is important if it "explains" much by little, that is, if it abstracts the common and crucial elements from the mass of complex and detailed circumstances surrounding the phenomena to be explained and permits valid predictions on the basis of them alone. To be important, therefore, a hypothesis must be descriptively false in its assumptions*

*…*

***To put this point less paradoxically, the relevant question to ask about the "assumptions" of a theory is not whether they are descriptively "realistic," for they never are, but whether they are sufficiently good approximations for the purpose in hand. And this question can be answered only by seeing whether the theory works, which means whether it yields sufficiently accurate predictions***(emphasis added)*.”*

# 1.0 What is wrong with scats volume, can it be machine learned ‘fixed’ or not?

## 1.1 Hierarchy of events leading to SCATS “volume calculations” VO, VK, DS.

To explore the hierarchical manner, in which events occur *in seriatim* to create SCATS Volume and associated metrics (e.g. VO, VK, DS), let us review a research dissertation using actual SCATS data from Dublin which explored the internal SCATS algorithms and limitations.

The following section contains excerpts from a dissertation designed to compare ‘extracted actual SCATS data’ to a testing framework involving an external to SCATS custom built algorithm (but using the internal SCATS data as source), to compare performance of traffic congestion management against ‘measures that are available in SCATS’.

One may interpret this dissertation effort as, ‘get the raw data out of SCATS and design an improved Algorithm to reduce traffic congestion and learn what’s going on’, another interpretation may be, ‘how badly is the SCATS algorithms performing against our own design, using the same data as SCATS actually uses’.

<https://www.scss.tcd.ie/publications/tech-reports/reports.00/TCD-CS-2000-46.pdf>

*“3.3.3 SCATS Traffic Measurements and Calculations*

*Two basic forms of traffic data are sensed by the each of the detectors and sent by the local controller to the regional computer at the end of every cycle. This data takes the form of:*

*• The number of gaps (where nothing is detected) that occurred between the vehicles and the total non-occupancy (or space) time that occurred during the lane’s green time. Non-occupancy or space-time is the amount of time (in seconds) during a lane’s green time that the detector has no vehicles travelling over it.*

*• The phase time for the lane plus any remaining or unused phase time. Remaining or unused phase time can occur if a local controller decides to end a phase prematurely, due for example, to a lack of available vehicles which wish to pass through the green light. From this raw data three fundamental values that are needed by SCATS for each lane can be calculated. These values are:*

*1. Original Volume (VO).*

*2. Degree of Saturation (DS).*

*3. Reconstituted Volume (VK).*

*The algorithms [Lowrie, 1982] used to create these values are described in further detail within the next sections.”*

Consider and count the underlying assumptions/dependencies existing above, elicited in the following observations: -

1. ‘Number of gaps’ is a ‘voltage drop’ (remember video showing vehicle detection), assuming the current/loop detector is not broken, this ‘voltage drop’ itself additionally is premised on a vehicle size of 4.5 meters and is subject to being affected by speed calibration when setting up the ‘gain’ of the signal.
2. ‘ending a phase may be decided by a local controller’ based on…not detecting a vehicle (i.e. ‘a lack of available vehicles which wish to pass through’).
3. All 3 ‘data’ calculations created by a Regional controller, (VO, DS, VK) manifest from a sourcing of loop detector information ‘passed from the local controller’.

This list of dependencies upon the faultless functioning of each lanes loop detector, is exacerbated by subsequent SCATS ‘calculations’ and further assumptions which SCATS applies to the raw sourced information from the loop detector, including ‘smoothing and damping’ data the loop detector provides (sic), to compensate for ‘occasional significant fluctuation’, attributed to ‘various causes’, viz.

*“SCATS Data Smoothing and Damping*

*The values of VO, DS and VK can occasionally fluctuate quite significantly (e.g. due to emergency vehicles passing through an intersection). It is therefore important that some form of averaging (or hysteresis) is performed on the data before it is used by SCATS. This process takes the form of weighted averages over a period of three cycles as described below:*

*AVO = 0.45(VO′) + 0.33(VO′′) + 0.22(VO′′′)*

*ADS = 0.45(DS′) + 0.33(DS′′) + 0.22(DS′′′)*

*AVK = 0.45(VK′) + 0.33(VK′′) + 0.22(VK′′′)*

*where:*

*AVO = Average Original Volume (vehicles per cycle)*

*ADS = Average Degree of Saturation (percent)*

*AVK = Average Reconstituted Volume (vehicles per cycle)*

*VO′ = Original Volume for this cycle*

*VO′′ = Original Volume for the previous cycle*

*VO′′′ = Original Volume for second-last cycle”*

The hierarchy of assumptions could continue to be (researched further and) built upwards, however there is a cogent observation that the dissertation was designed to identify, test and analyse, which informs a careful reader that make any continued pursuit somewhat moot, viz.

*“what is not trivial is to calculate a meaningful measure of congestion from this data. The difficulty in creating a meaningful congestion algorithm lies in the fact that SCATS is an adaptive UTC. This means that the traffic conditions that cause undue delays at an intersection for one moment in time may not cause any delays a different time. This is because as a strategic approach becomes busier SCATS adjusts the timing of the lights to compensate and allows greater numbers of vehicles through. An example of this would be where a group (also called a platoon) of twenty vehicle approach an intersection at a certain moment in time then they may not all get through the intersection in one cycle, thereby creating a queue. After this SCATS then adjusts the lights to compensate and at the next cycle a platoon of twenty cars can get through the intersection in the same cycle. This illustration shows how for any congestion algorithm to be effective it must take into account the current state of SCATS (i.e. its current ability to compensate for congestion) as well as the actual flows of traffic at an intersection.*

*…*

*Figure 5.3 shows the basic congestion algorithm that was in use at the time of writing this dissertation. The basic idea behind this algorithm come from the SCATS definition of congested operations (Chapter 3). As can be seen there are eight separate conditions that can be present and detected. The algorithm starts by trying to satisfy the most congested condition (i.e. congestion Value = 6). If this condition is not satisfied the then the algorithm continues through the conditions until a match is found. If no match is found then the congestion Value is set to zero. An explanation for each of the terms in the maximum congestion level condition (line 143) is as follows:*

*…*

*Most of the other rules are variations on the above conditions for lighter levels of congestion. The one exception to this is the rule where VO and VK are both zero. This situation normally occurs under two different conditions. The first situation could be late at night when no vehicles pass through a lane during one whole cycle.* ***The conditions could also be met when a detector is faulty and is no longer detecting the vehicles as they pass by. As there is no reliable way to tell the difference between these two conditions it was decided for the time being to let the human user decide for themselves which situation was resulting in the conditions being met, e.g. if a congestion measure of zero is being flagged on a normally busy road during rush hour then is it probable that the detector is faulty.*** *A method of automating this decision process might be to factor in the time of day as well as the length of time that a congestion measure has been at zero for.”*

Of note, SCATS an otherwise closed system built to function on a pyramid of assumptions, is fundamentally premised upon faultless operation of loop detectors. The next level of pyramid assumption is a deliberate concession built into SCATS making accommodations for 3 consecutive/contiguous phases of ‘unusual events’ (think emergency vehicle), to ‘3 phase weighted average calculates the volume’ (by the regional controller?) and make consequential determinations.

Finally, critically and a fortiori, SCATS for *“the first time being lets humans decide for themselves if a detector is faulty and to otherwise ignore the SCATS calculations and operations (paraphrased)”*. This concession, ultimately relies on user knowledge to displace SCATS calculations and ignore the erroneous volume calculations based on SCATS utter dependency upon faultless operation of loop detectors.

Can we find this feature *“*(that) *SCATS involves human user to decide for themselves if a detector is faulty and no longer detecting vehicles as they pass by.”* and make necessary traffic management decisions, anywhere in the SCATS promotional materials available online today, alternatively will the ‘caveat emptor’ raised in the above dissertation be raised by the vendor?.

<http://www.scats.com.au/files/an_introduction_to_scats_6.pdf>

Relevantly,

*“(SCATS) continuously and autonomously self-calibrates efficient traffic conditions and measures road utilisation at each detector. Calibration and measurements are used to estimate the balance of: the traffic signal and road capacity supply, and the traffic demand–in each vehicular lane, and optimise and allocate scarce road resources, accordingly.*

*SCATS dynamically balances the local site optimisation and inter-site coordination to capture the efficiency benefits of platoon progression*

*…*

*In SCATS parlance, SCATS decision-making occurs at two levels: strategic and tactical (6).*

*At the strategic level: SCATS dynamically balances the needs of a coordinated network such as achieving offsets to aid platoon progression, with the needs of the local site such as the appropriate phase sequence and the balance of phase (stage) allocation given demand.*

*Strategic control is managed by the regional computers. Using flow and occupancy data collected from vehicle detectors the regional computer determines on an area basis the optimum cycle length, phase splits, and offsets to suit the prevailing traffic conditions.*

*Strategic control bases its adjustments on a traffic demand measurement known as ‘Degree of Saturation’ (DS). However, in this context, DS represents how effectively the road is being used. Using the in-ground loop detectors at the critical intersections, the local controller collects flow and occupancy data during the green phase. The data is sent to the regional computer which calculates …”*

One may opine, the official SCATS manual is less than helpful on targeting readers to potential issues of concern. Another source for assistance may be the New South Wales (NSW) Government brochure, which relevantly concedes, “SCATS support manual overrides”.

<http://www.qtcts.com.au/media/512152-RTA532_SCATS_A4_Product_Brochure_07.pdf>

Alternatively, Taiwan University courses contain materials publicly accessible that align with prior analysis of the functionality of SCATS loop detector ‘information’ looking at space between vehicles, viz.

*SCATS operated by looking at “Space” between vehicles*

* *There is a relationship between traffic density and Space time.*
* *Degree of Saturation – measure of effectiveness of green time.*

*The detection information are preprocessed in the controller and sent to a regional computer to calculate “DS.*

<http://ocw.nctu.edu.tw/course/sc011/2012-08-21.pdf>

## 1.2 Synthesis: SCATS hierarchical (pyramid) accuracy depends on faultless loop detector operation

It can be observed, the 2 phenomena captured by a loop detector, form the singular point of failure for the entire SCATS volume system. Should the loop detector be faulty, the collapse of the SCATS designed pyramid creating Volume and other metrics, inwardly fails spectacularly, regardless of whether this is captured by a user, the ultimate downstream/end user of VO, VK and DS get ‘kicked the can (of worms)’ without any actual way to reconstruct as reality passed by without being captured.

## 1.3 What research exists into loop detector failure, and what frequency of failure exists?

What is a loop detector, what does a loop detector look like and can you build your own loop detector?

<https://www.youtube.com/watch?v=MQTHcKgDRto#t=5m28s>

What does professional installation of loop detectors look like?

<https://www.youtube.com/watch?v=OFpnJZ_jF68#t=2m05s>

## 1.4 Is there a World recognized body, who can authoritatively assert failure rates for loop detectors?

If we could learn from, say, a relevant Federal Transportation Administrative body, responsible for interacting with 51 American States as a source of authority to assert anything they have learnt from loop detector failures, perhaps we could learn from a 1993 U.S. Department of Transportation, Federal Highway Administration Training Video, viewable from VHS transcoded to YouTube, entitled:

"Federal Highway Administration Video VH-584 Traffic Detector Video Training Course - Part 1 - Detector Theory"

<https://www.youtube.com/watch?v=0VNMSrnkNAg&list=PLb2EQf-uAPqh7l9H6sI4nHKqurKyJP8AF&index=1&#t=1m56s>

Interestingly, 25 years ago this video canvasses 7 different technologies then considered “state of the art” and “technologically advanced’.

<https://www.youtube.com/watch?v=0VNMSrnkNAg&index=0&list=PLb2EQf-uAPqh7l9H6sI4nHKqurKyJP8AF#t=12m37s>

Loop detectors were observed to have a relatively short life, leading to high and prolonged maintenance costs;

*"need new technology ! loops have a relatively short life, for a variety of reasons, therefor we are also looking into substitutes for loop detectors - which are at least as accurate as loop detectors"*

<https://www.youtube.com/watch?v=0VNMSrnkNAg&index=0&list=PLb2EQf-uAPqh7l9H6sI4nHKqurKyJP8AF#t=13m51s>

Interestingly, 25 years ago this video canvasses an emerging video based traffic detection, providing;

*"occupancy, volume, queue lengths and speed...this technology has been refined to a point, that field evaluations are currently being made."*

<https://www.youtube.com/watch?v=Q6EpYiR1Mc4&index=1&list=PLb2EQf-uAPqh7l9H6sI4nHKqurKyJP8AF#t=11m24s>

The discussion repeats, discusses and addresses continuous drawbacks of loop detector and their consequential failure to operate faultlessly, in terms of size, shape and other dimensions which combine to increase the chance of numerous types of loop detector failures.

<https://www.youtube.com/watch?v=Q6EpYiR1Mc4&index=1&list=PLb2EQf-uAPqh7l9H6sI4nHKqurKyJP8AF#t=12m55s>

Interestingly, the environment loop detectors were situated within, namely roads, were identified as blameworthy, together with the unfortunate speed careless motorist operated vehicles at, viz.

*"frequent failure due to pavement cracks..." and "low speed, high speed, each have to be configured etc etc to avoid loop detector failure"*

<https://www.youtube.com/watch?v=Q6EpYiR1Mc4&index=1&list=PLb2EQf-uAPqh7l9H6sI4nHKqurKyJP8AF#t=16m22s>

The dominant breakage point, interestingly, where loop detectors are installed, is in and around the ‘dilema zone’ contributing to ‘pavement cracks’ and motorist behaviour and decision making, culminating in further issues for loop detector failure;

*"dilema zone issues, plaguing designers for years."*

<https://www.youtube.com/watch?v=SFmSuVee_GI&list=PLb2EQf-uAPqh7l9H6sI4nHKqurKyJP8AF&index=2#t=0m17s>

Interestingly, ‘sloppy installation’ creating loop detector failure, was identified arising from contractor work to install loop detectors, an unfortunate accusation against individuals whose income depended upon loop detector installation;

*"carefully development, planning, theory, can be sabotaged by sloppy installation …creating detector failure..."*

<https://www.youtube.com/watch?v=SFmSuVee_GI&list=PLb2EQf-uAPqh7l9H6sI4nHKqurKyJP8AF&index=2#t=5m59s>

Penultimately, the authoritative U.S. Department of Transportation, Federal Highway Administration survey across multiple States into loop detector failure, presented a finding of an estimated constant (at any point in time across all surveyed states) 25% loop detector failure existed across America, viz.

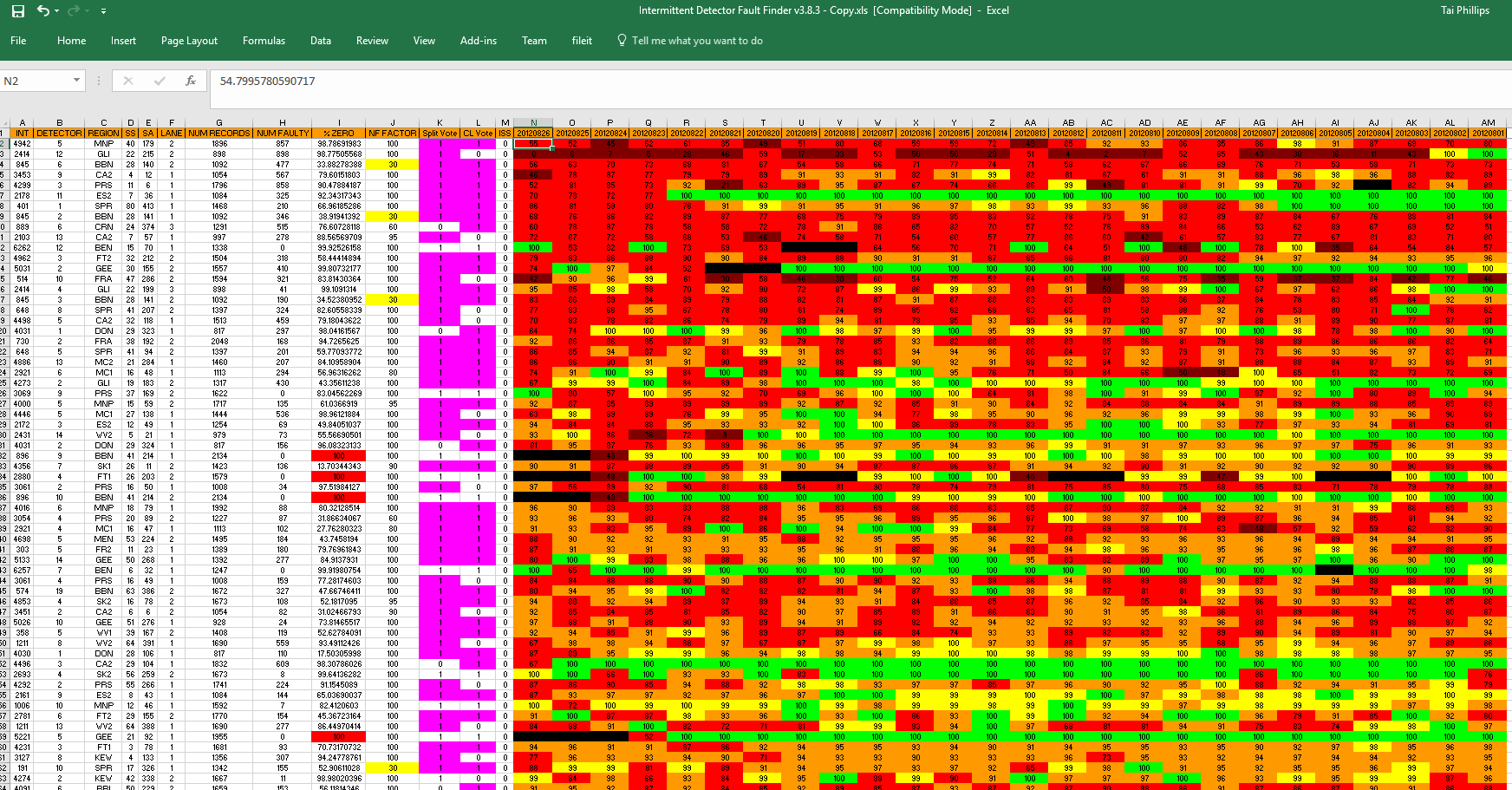
*"the large number of failures nationwide has created a deep concern within the traffic engineering community. A number of studies have traced many loop detector failures, to a problem with the in-road loop wire, or to the splice between the lead in wire and cable. These failures are usually due to bad pavement conditions or sloppy installation techniques. Several state agency surveys have noted, that at any given time up to 25% of their installed loop detectors are not operating properly."*

**To restate, a continuous (at any point in time) 25% loop detector failure was estimated across all surveyed U.S. States, as reported by the U.S. Department of Transportation, Federal Highway Administration.**

<https://www.youtube.com/watch?v=SFmSuVee_GI&list=PLb2EQf-uAPqh7l9H6sI4nHKqurKyJP8AF&index=2#t=6m23s>

## 1.5 Does VicRoads have any technology to detect loop failure, if yes, what is the level and continuity of failure?

VicRoads in Journey Services developed and uses a excel tool to identify maintenance issues which are impacting on the operation of the traffic signal network. This is a role that can/should be fulfilled in the future by Smart Journey Systems maintenance teams. The tool is the “Intermittent Detector Fault Finder v3.8.3.xls” :-



This tool, when run, presents a daily level of detector failure as the level of detail of each green light phase would go beyond neatly fitting onto the screen above.

## 1.6 How does the 25% across the United States of America at an estimated 25% constant failure rate, compare to VicRoads today ?

As for the current VicRoads failure rate for loop detectors, if we isolated only 1 ‘data’ created as a result of loop detector failure (there are more than 1 type of failure to identify) as measured in the above tool (Degree of Saturation “DS”), Smart Journey Systems maintenance teams and Journey Services may be asked to provide a response.

## 1.7 Is loop detector failure, measured by DS (degree of saturation) the only data issue created by reliance on loop detectors?

No. Chatter (excessive counting caused by e.g. bus or truck braking), Lane Discipline (car triggering 2 lane detectors) and other contributory variables combine to make reliance upon a broken system of loop detectors, unfeasible as the source of ground truth – as each of these emanate faulty data from failing loop detectors.

# 2.0 Ought Computer Vision, overcome, replace, correct what we know about ‘SCATS volume errors’?

To establish ground truth, in terms of “*occupancy, volume, queue lengths and speed*”, we need a “*technology* (that) *has been refined to a point, that field evaluations are currently being made.”*. This is a 25 year old quote made in the above 1993 U.S. Department of Transportation, Federal Highway Administration training video, based on their having conducted numerous surveys across numerous U.S. States which had led to the assertion, that they collectively had a constant/at any point in time a 25% detector failure…causing “*the large number of failures nationwide* (having) *created a deep concern within the traffic engineering community*”*.*

A 20 minute presentation of Computer Vision in May 2018, encompassing the plethora of exhaustive solutions to the issues faced in the Victorian Urban Arterial road network, is unworkable, so what follows is a list of links for self review. Note, each is based on freely available open source code which any person, company, (e.g. VicRoads) can internally implement without, royalties, intellectual property payments or reliance on external vendors if they choose to pursue such an approach:-

BOX: LaTrobe Street, Melbourne, YOLO Tram Real time

<https://www.youtube.com/watch?v=BNHJRRUKMa4#t=2m01s>

MASK: Singapore

<https://www.youtube.com/watch?v=UWtac4cFERM>

Exception

<https://www.youtube.com/watch?v=ATlcEDSPWXY&t=40s>

Combined COCO RCNN

<https://www.youtube.com/watch?v=OOT3UIXZztE&t=44s>

No simplistic listing of the free open sourced computer vision technologies is adequate to represent the list of International companies (Facebook, Google, Microsoft, Nvidia, Baidu, etc etc) who are in a race to ‘gain market share’ of their technology stacks to avoid losing relevance – by deliberately freely providing deep learning and convolutional neural network, frameworks and production pipelines, that the author opines ought to be pursued within VicRoads.

Let us consider as an example, 1 International Companies providing free code, models, libraries to utilize for development of all the above Computer Vision examples, namely, Facebook. <https://facebook.ai/developers> and <https://github.com/facebookresearch/Detectron> . In support of the above proposition, that code, frameworks for deep learning, AI, RCNN’s etc etc be given royalty free to the public, let us trace 1 example utilising the researched and free to use code.

Original SIFT/HOG based Brazil work.

<https://www.youtube.com/watch?v=3IaKJuZN55k&list=PLb2EQf-uAPqhQ5Cx2I2FLiSRkafYFmhg9&index=3&t=0s>

Using Szegedy and Girshick research (code freely available from Google and Facebook) and implementation of a CNN for region based licence plate detection was published in 2017.

<https://www.youtube.com/watch?v=K91QsELclac&list=PLb2EQf-uAPqhQ5Cx2I2FLiSRkafYFmhg9&index=1&t=0s>

Published paper in China, September 2017.

<https://www.researchgate.net/publication/320023942_Convolutional_Neural_Networks_for_License_Plate_Detection_in_Images>

Using the above code, and dataset provided by Brazil, 1 week of implementation at LaTrobe University created a ‘work in progress’ version.

<https://www.youtube.com/watch?v=eZSMIRGydAU&list=PLb2EQf-uAPqhQ5Cx2I2FLiSRkafYFmhg9&index=10&t=0s>

For simplistic blob based detection, similarly freely available code and tutorials are available.

<https://www.youtube.com/watch?v=Y3ac5rFMNZ0#t=5m23s>

<https://github.com/MicrocontrollersAndMore/OpenCV_3_Car_Counting_Cpp/blob/master/main.cpp>

<http://www.learnopencv.com/blob-detection-using-opencv-python-c/>

To illustrate failure points of any single approach, I have prepared training videos for VicRoads engineers who are testing Blob Based detection on CCTV, so that they may ‘Count cars’ on existing CCTV cameras, free of cost. This may develop understanding of appropriate placement of cameras for computer vision purposes.

<https://books.google.com.au/books?id=LPm3DQAAQBAJ&pg=PA428&lpg=PA428&dq=opencv+contour+area+overlap&source=bl&ots=2vJnVifdyf&sig=G3cjvfdpceyHp28wee0_AJJjFyM&hl=en&sa=X&ved=0ahUKEwj-y5Pxu_DaAhXI6J8KHf5BBmcQ6AEIWTAJ#v=onepage&q=opencv%20contour%20area%20overlap&f=false>

Mathematical blob overlap detection

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3660981/>

## 2.1 Is a one method approach for Computer Vision proposed, as the best solution?

No, combining multiple technologies, with multiple failsafe is required. A audit trail with a person performing once a week randomised checking of video data quality is an additional failsafe.

<http://www.abc.net.au/news/2018-05-06/ffa-reveal-reasons-behind-var-controversy-a-league-grand-final/9732640>

# 3.0 Where to next, what are the next steps?

