Future Technologies of War

Robotics, AI and Autonomy: Moving Beyond The Hype to a Deeper Understanding

Professor Michael Milford
Acting Director
QUT Centre for Robotics

QUT Centre for Robotics

123rf.com / Jesse-lee Lang

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123rf.com / yukipon

Introductions

Robotics

Autonomous vehicles

Sensing

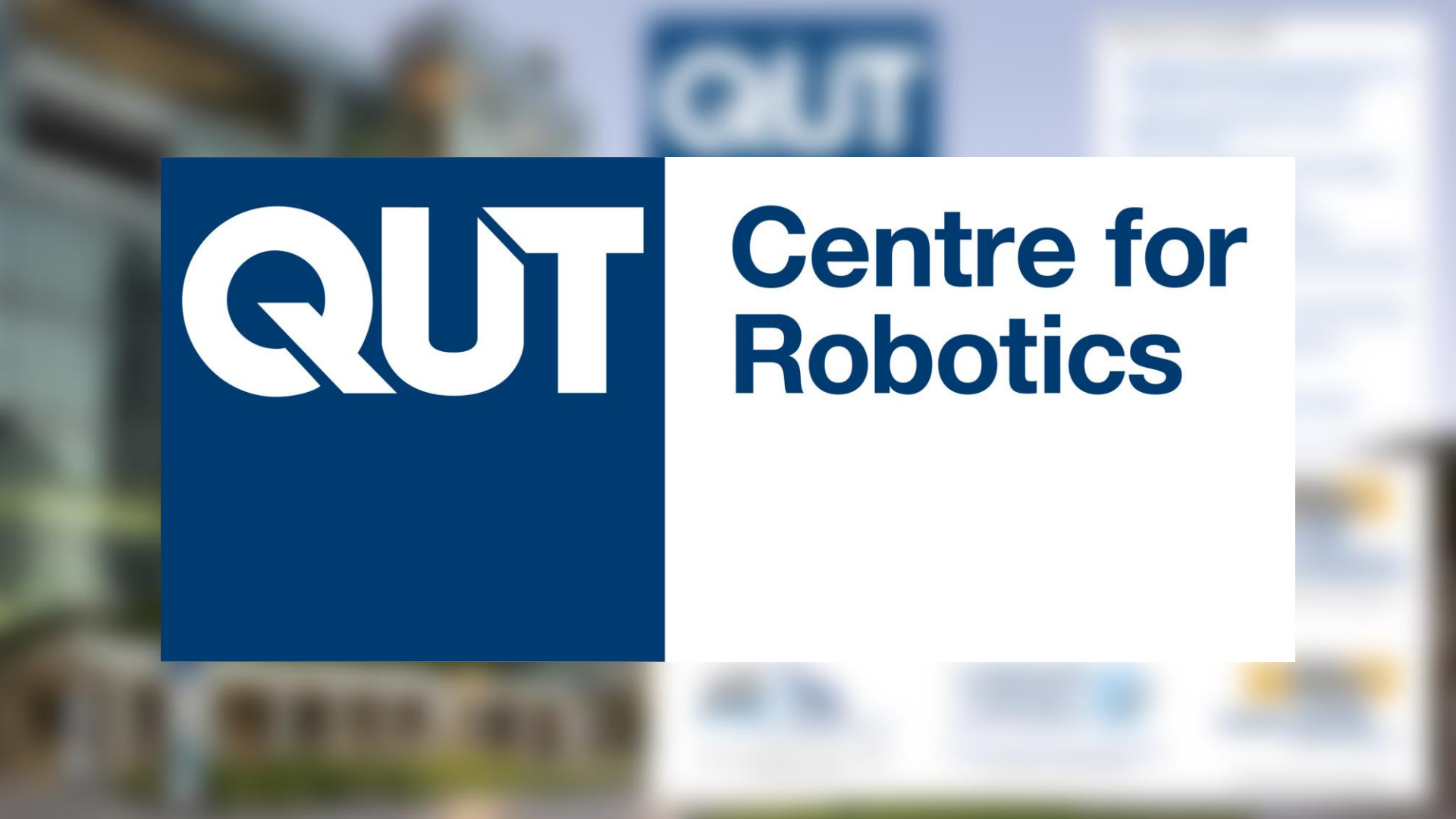
Artificial Intelligence

Throughout Talk

123rf.com / senoldo / Christos Georghiou / Hong Li / zmiter / John Schwegel / lassedesignen / Guido Vrola / Anastasy Yarmolovich / Katarzyna Białasiewicz

QUT Centre for Robotics

Introductions


QUT
Centre for
Robotics

QUT Centre for Robotics

About Us

Our centre

Continues on from over 10 years of investment in Robotics at QUT

Formed in January 2020

Initial 4 years with option to continue

To be at the forefront of research and innovation in intelligent robotics

100+ members, including 16 CIs, 19 AIs and 50+ HDRs

Our research programs

Physical interaction	Led by Distinguished Prof Peter Corke
Perception & localisation	Led by Professor Michael Milford
Decision & control	Led by Professor Jason Ford
Visual learning & understanding	Led by Assoc. Professor Niko Suenderhauf
Human interaction	Still in formation

Robotics, Automation & Autonomous Vehicles at QUT

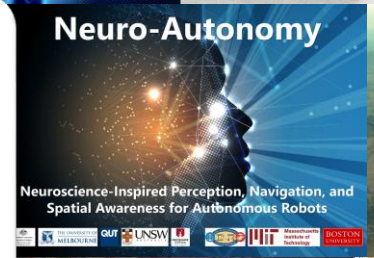
QUT Centre for Robotics

ARM Advanced Robotics for Manufacturing HUB

ARC Ind
Transformati
Centre for Co
Robotics in
Manufac

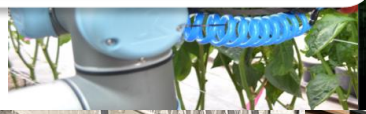
AUSTRALIAN CENTRE FOR ROBOTIC VISION

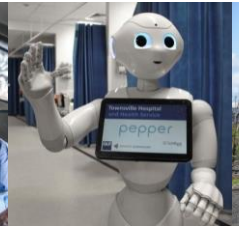
New $44M ARC Centre of Excellence bid with Defence Component

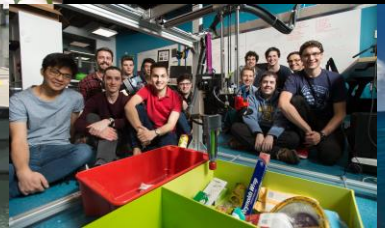


ARC Industrial Transformation Training Centre for Joint Biomechanics

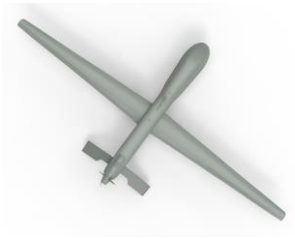
Australian Research
Special Research In
Excellence in Antarc
Securing Antarc
Environmental Future' (SAEF) research program

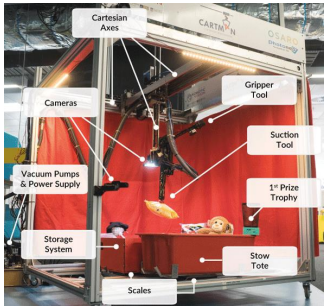






Bridging the Divide Between World Class Fundamental Research with Deployed and Fielded Autonomous Systems up to High TRL Levels





Collaborations and Connections with Over 100 Leading International Companies, Startups and Universities

Beyond defence, a significant number of the Fortune 500 and top 100 universities

Flexible Working Models:

Teams: From Single Team Projects to Major International Collaborations

Nature of Work: From blue sky fundamental research to high technology readiness level

Example 1

Example 2

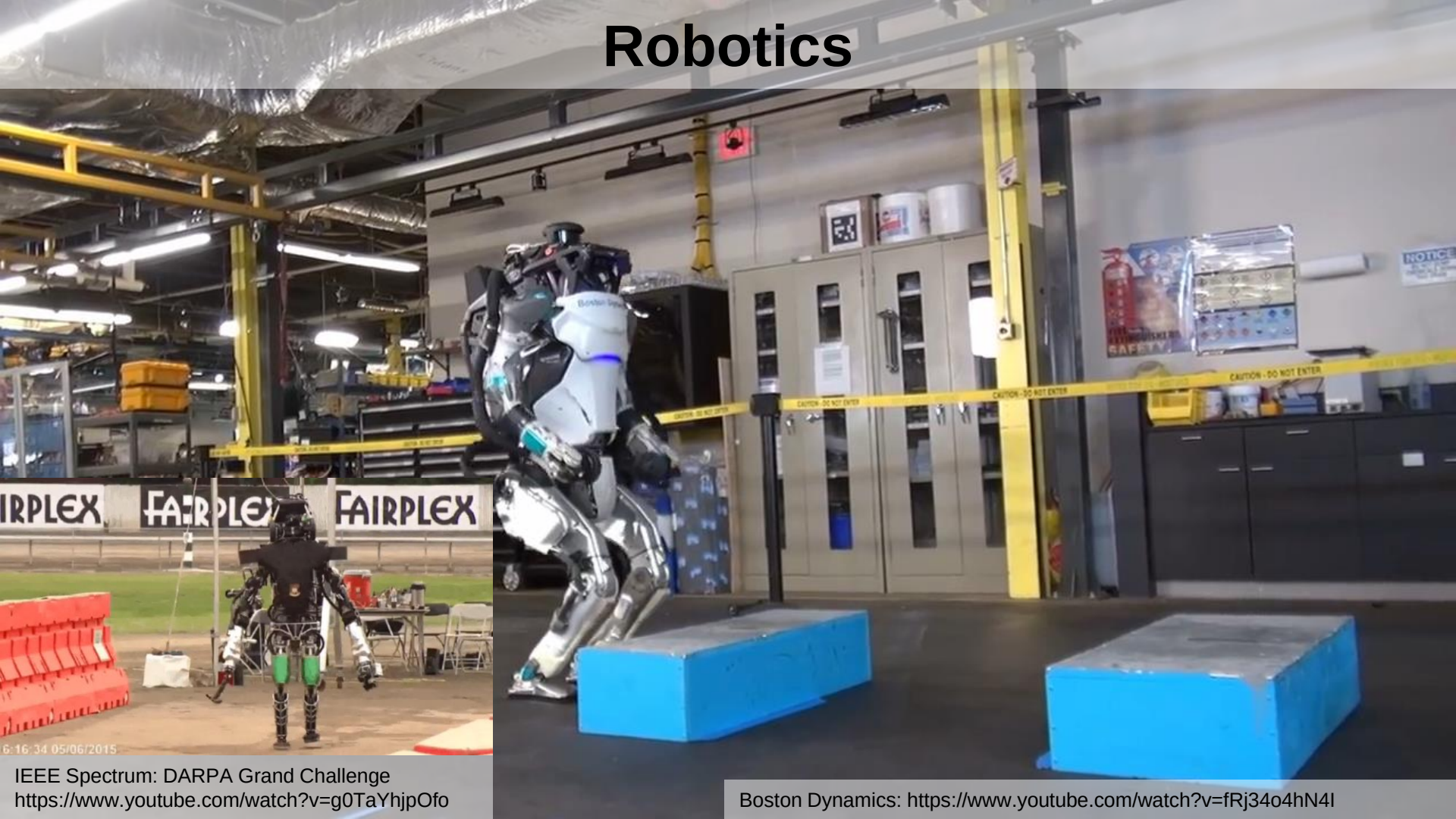
- **Rheinmetall Autonomous Combat Warrior (ACW) Program (w/ CSIRO, DSTG, RMIT)**
- **Advanced Terrain Detection (ATD) for Autonomous Ground Vehicle**
- **in collaboration with CSIRO/Data61**
- **Terrain traversability estimation using sensor data fusion**
- **Semantics: identify mud, water, rocks, sand, vegetation etc.**
- **+ 3D information (Geometry)**
- **=> Traversability for Autonomy**

Robotics

> 10,000,000 Roombas sold

My robot vacuum cleaner foolishly attempting to escape down the stairs during experiments

Robotics



IEEE Spectrum: DARPA Grand Challenge
https://www.youtube.com/watch?v=g0TaYhjpOfo

Boston Dynamics: https://www.youtube.com/watch?v=fRj34o4hN4I

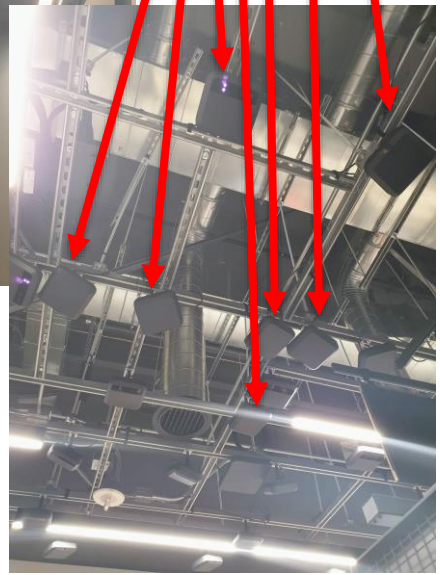
Robotics and Automation

Half hour run time
Price likely in the low to mid 6 figures

Boston Dynamics

Boston Dynamics: https://www.youtube.com/watch?v=fUyU3IKzoio

Robotics and Automation: Retail and Point of Sale



Ports and Mining

RioTinto

Our business | Investors | Careers | Media

Global home > Media > Media releases > Rio Tinto to expand autonomous fleet as part of $5 billion productivity drive

18 December 2017

Rio Tinto to expand autonomous fleet as part of $5 billion productivity drive

SHARE

Rio Tinto to expand autonomous fleet as part of $5 billion productivity drive
PDF 102 KB

Rio Tinto will expand its fleet of autonomous haul trucks at its world-class iron ore operations in the Pilbara by more than 50 per cent by 2019 after signing agreements with leading manufacturers Caterpillar Inc. and Komatsu Ltd. to convert traditional trucks to autonomous vehicles.

A total of 29 Komatsu haul trucks will be retrofitted with Autonomous Haulage System (AHS) technology starting next year. The project at the Brockman 4 operation is scheduled for completion by mid-2019, allowing the mine to run entirely in AHS mode once fully deployed.

Automation occurring relatively quietly in the background, out of direct sight

itnews

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Brisbane Port moves closer to full automation

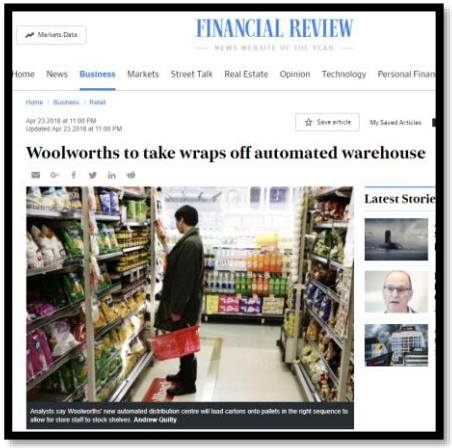
By Staff Writers
May 23 2014
9:09AM

1 Comment

Second major tenant completes robot rollout.

Stevedoring firm DP World Australia has taken the wraps off $250 million in upgrades designed to enable "semi-automated" operations at its Port of Brisbane container terminal. The company — which is majority-owned by Citigroup — has invested in 14 automated stacking cranes ...

Logistics



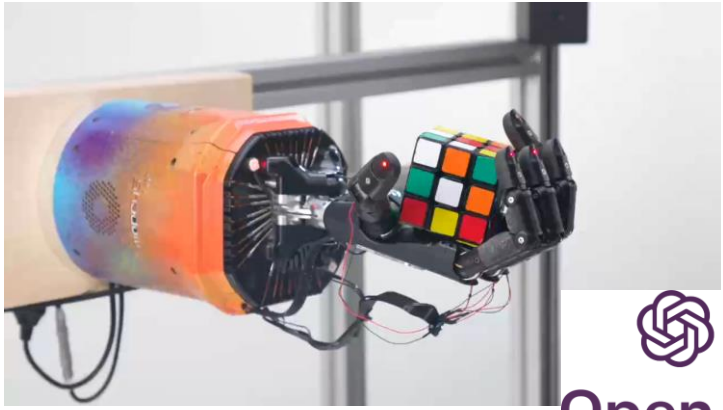
Again, mostly occurring relatively quietly in the background out of direct sight

Hardware is HARD

Progress will usually be relatively slow with anything affected by the laws of physics, e.g.:

- energy storage,
- sophisticated physical robot components like hands & grasping,
- dynamics of walking

Some of the Key Technologies



OpenAI

Grasping and Manipulation

Mapping, Positioning & Navigation

Sensing and Understanding

Autonomous Vehicles: Current State of Play

123rf.com / cheskyw

Massive Consolidation of Key Players

Google Self-Driving Car Project

WAYMO

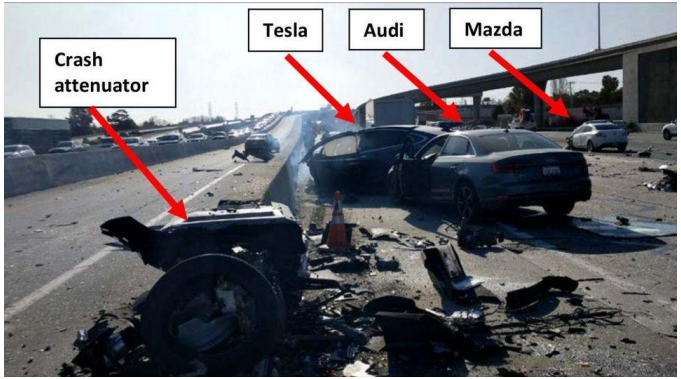
Tech Company Corporate Example: Waymo/Google

Other key companies:

- **GM Cruise**
- **Tesla**
- **Hundreds more at varying scales…**

https://www.youtube.com/watch?v=uHbMt6WDhQ8

High Profile Incidents and Low Profile Benefits



123rf.com / Tomasz Wyszolmirski

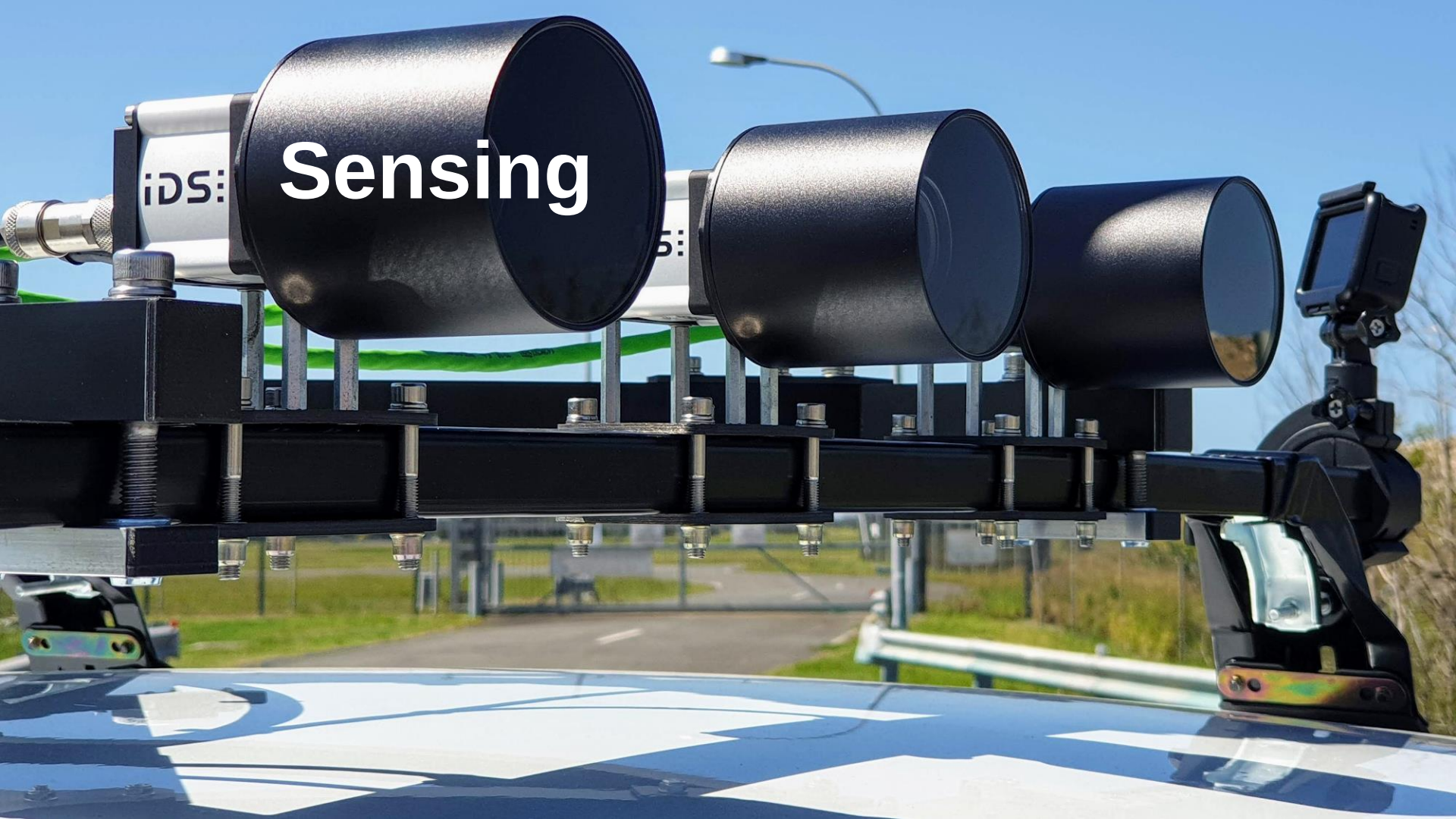
https://www.forbes.com/sites/bradtempleton/2019/05/03/lawsuit-over-tesla-autopilot-fatality-unlikely-to-win-but-it-uncovers-real-issues/#57b4a8f76034

The Big Challenge: Human Interaction

https://www.youtube.com/watch?v=VG68SKoG7vE

Corner Cases and Generalization

https://www.youtube.com/watch?v=GihuUYmoMXU

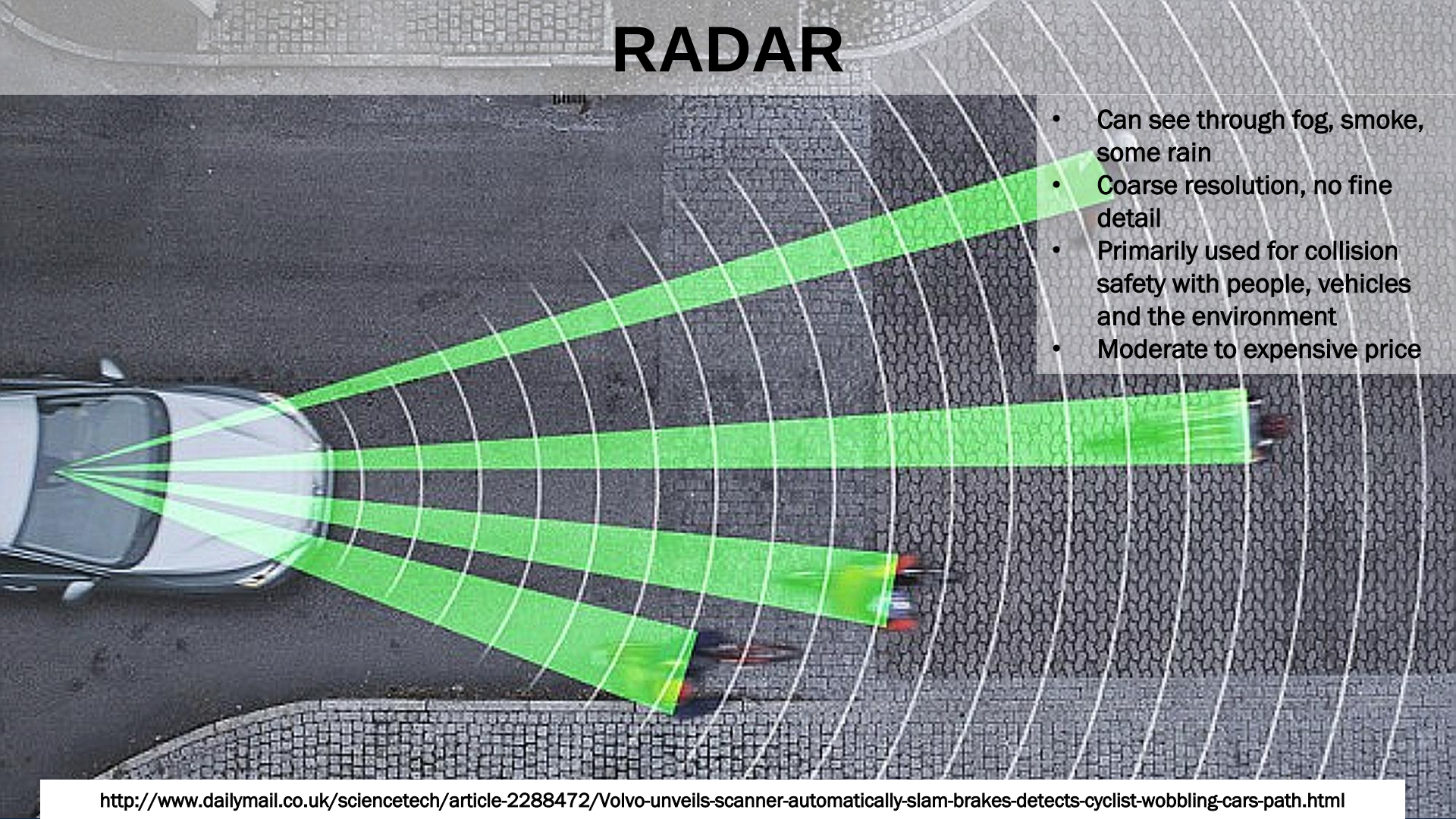

Sensing

GPS

- Provides position, good for journey planning
- Satellite-based, not 100% reliable (tunnels, urban canyons)
- “Autonomy-enabling” still not universally available (drop outs, accuracy, latency)
- Almost universal assumption that it can’t be used as primary source of positioning information

https://www.youtube.com/watch?v=C5s1ucmiACU

RADAR



- Can see through fog, smoke, some rain
- Coarse resolution, no fine detail
- Primarily used for collision safety with people, vehicles and the environment
- Moderate to expensive price

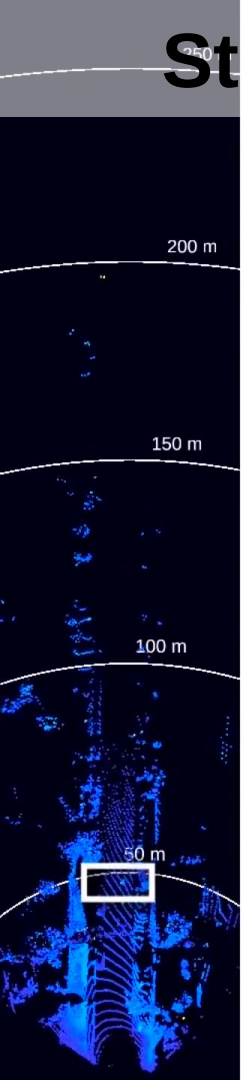
http://www.dailymail.co.uk/sciencetech/article-2288472/Volvo-unveils-scanner-automatically-slam-brakes-detects-cyclist-wobbling-cars-path.html

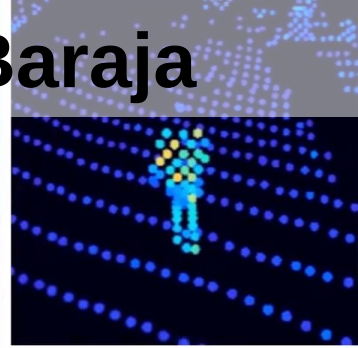
LIDAR

- 3D scan of range to all line of sight objects in all directions
- Medium resolution, high range accuracy
- Disrupted by heavy rain, particulates
- Good for detecting vehicles, pedestrians, mapping and positioning
- Expensive

In-car photo by Michael Milford. Google Self-driving Car, Velodyne

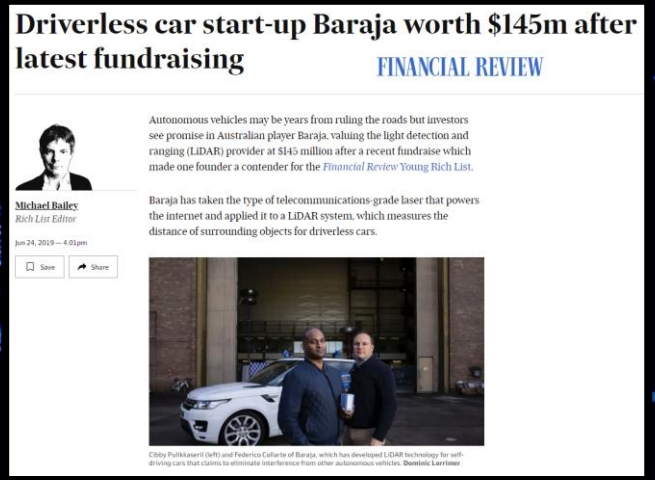
Still some innovation in the area e.g. Baraja





Dynamic region-of-interest adjustment

Preferentially increase resolution in key areas



Driverless car start-up Baraja worth $145m after latest fundraising

FINANCIAL REVIEW

Michael Bailey
Rich List Editor

Jun 24, 2019 — 4:01pm

Save Share

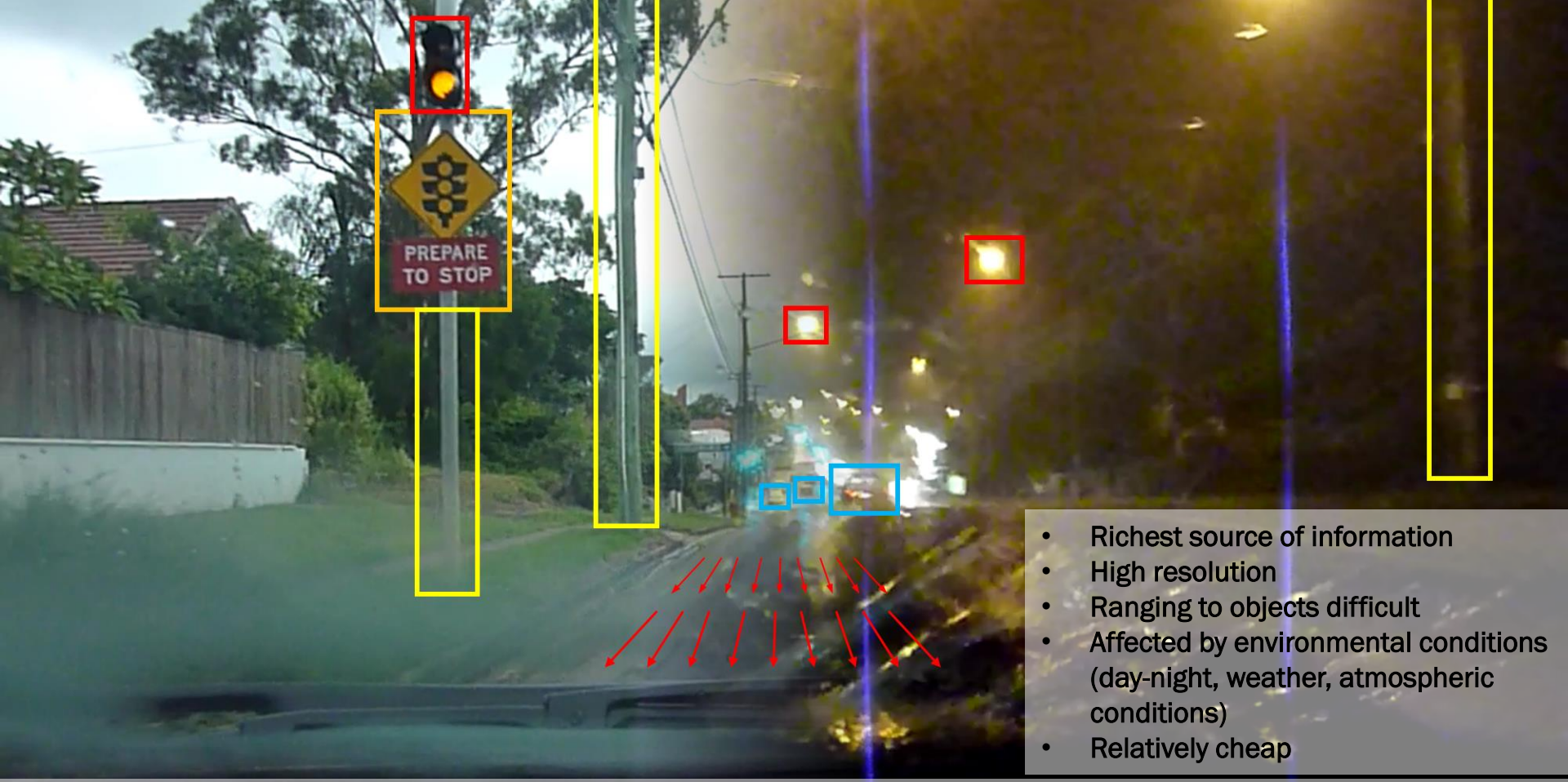
Autonomous vehicles may be years from ruling the roads but investors see promise in Australian player Baraja, valuing the light detection and ranging (LiDAR) provider at $145 million after a recent fundraise which made one founder a contender for the *Financial Review* Young Rich List.

Baraja has taken the type of telecommunications-grade laser that powers the internet and applied it to a LiDAR system, which measures the distance of surrounding objects for driverless cars.

Cibby Pulikkaseril (left) and Federico Collarte of Baraja, which has developed LiDAR technology for self-driving cars that claims to eliminate interference from other autonomous vehicles. **Dominic Lorrimer**

https://www.baraja.com/product/

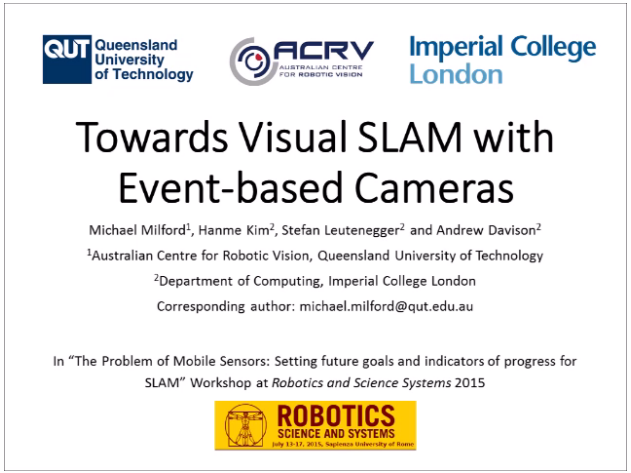
50m

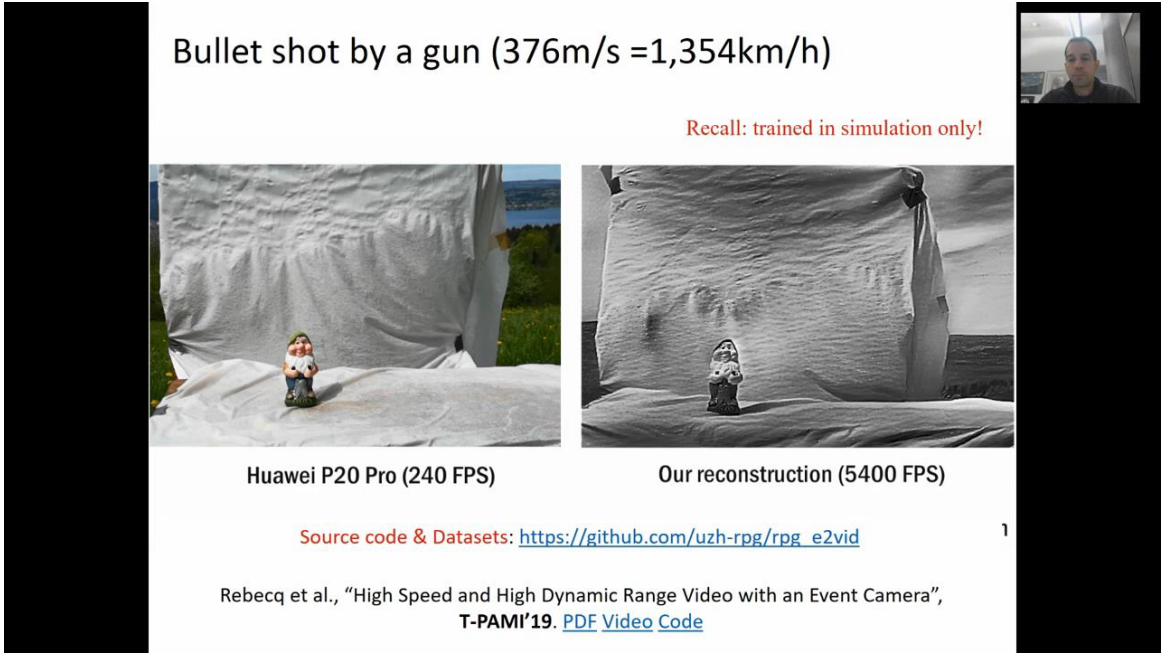


- Richest source of information
- High resolution
- Ranging to objects difficult
- Affected by environmental conditions (day-night, weather, atmospheric conditions)
- Relatively cheap

VISION (CAMERAS)

Camera Innovation Example: Dynamic Vision Sensors





- **Low power**
- **Low latency**
- **High dynamic range**
- **Edge perception potential**

Event Cameras: Opportunities and the Road Ahead (CVPR 2020), Davide Scaramuzza, Robotics and Perception Group, Dept. of Informatics, University of Zurich, and Dept. of Neuroinformatics, University of Zurich and ETH Zurich, Switzerland
https://youtu.be/6Sn9-M7qXLk

Connectivity

A range of other sensors

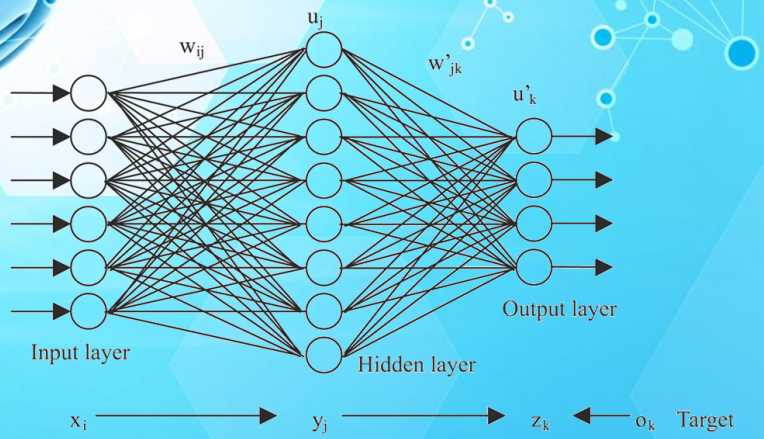
Accelerometers, IMUs

Sonar, throttle, fuel mix, power draw, all sorts of other instrumentation

Wheel encoders

123rf.com / dolgachov

Onboard Driving Intelligence



123rf.com / efks

Positioning and Localisation

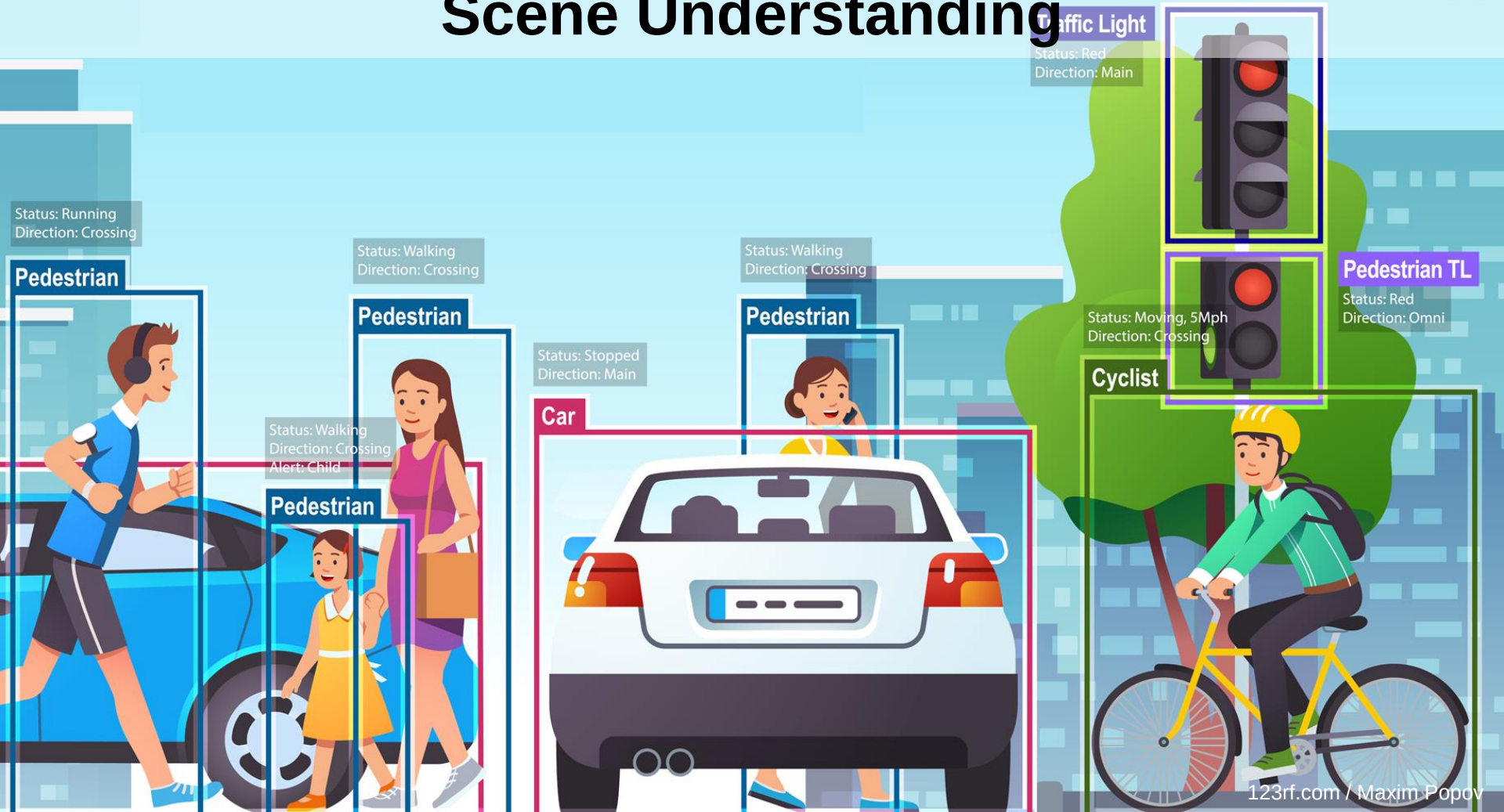
123rf.com / hkeita

Knowing When You Don't Know: Simple Example

- Which is better?
  - **System 1:** A positioning system that is fit-for-purpose **99.9%** of the time but lacks self-diagnosis capability, or
  - **System 2:** A positioning system that is fit-for-purpose **99%** of the time, and self-diagnoses that it's unfit-for-purpose **99% of the remaining time**?

- Using System 1, you'll make decisions based on incorrect positional information **0.1%** of the time.
- Using System 2, this drops to **0.01%**. System 2 is hard to create.

Scene Understanding



Recognition is often not enough

Most autonomous systems operating in complex environments with people and other autonomous systems also need:

- Intent understanding
- Prediction
- Scenario planning
- Contextual understanding

123rf.com / ostapenko

Better Sensors Solve Some but not All Problems

Navigation and Control Based on Task Constraints

123rf.com / Andrey Suslov

The AI Story

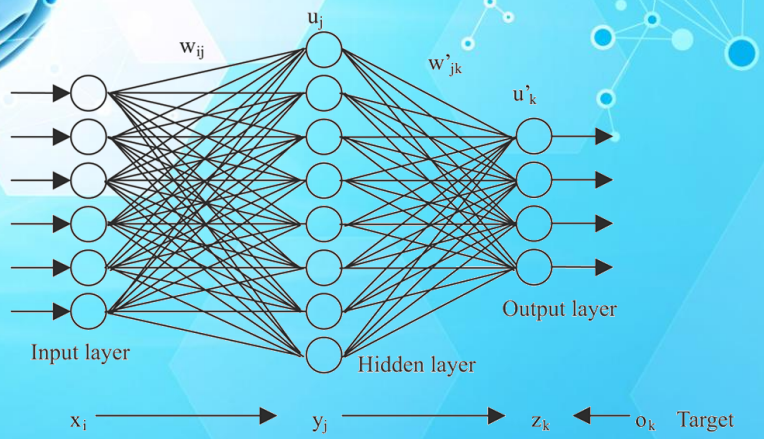
https://www.youtube.com/watch?v=VG68SKoG7vE

- You can make an entirely safe AV today that is entirely unusable
- Good engineering, connectivity or infrastructure improvements (crutches) can solve some but not all remaining challenges
- Unpredictable, highly varied vulnerable road users (VRUs) are arguably the most difficult challenge for AVs
- It's likely significant advances in driving intelligence – AI – will be required
- AVs' biggest impact may be outside the AV domain: new levels of AI, which will impact everything

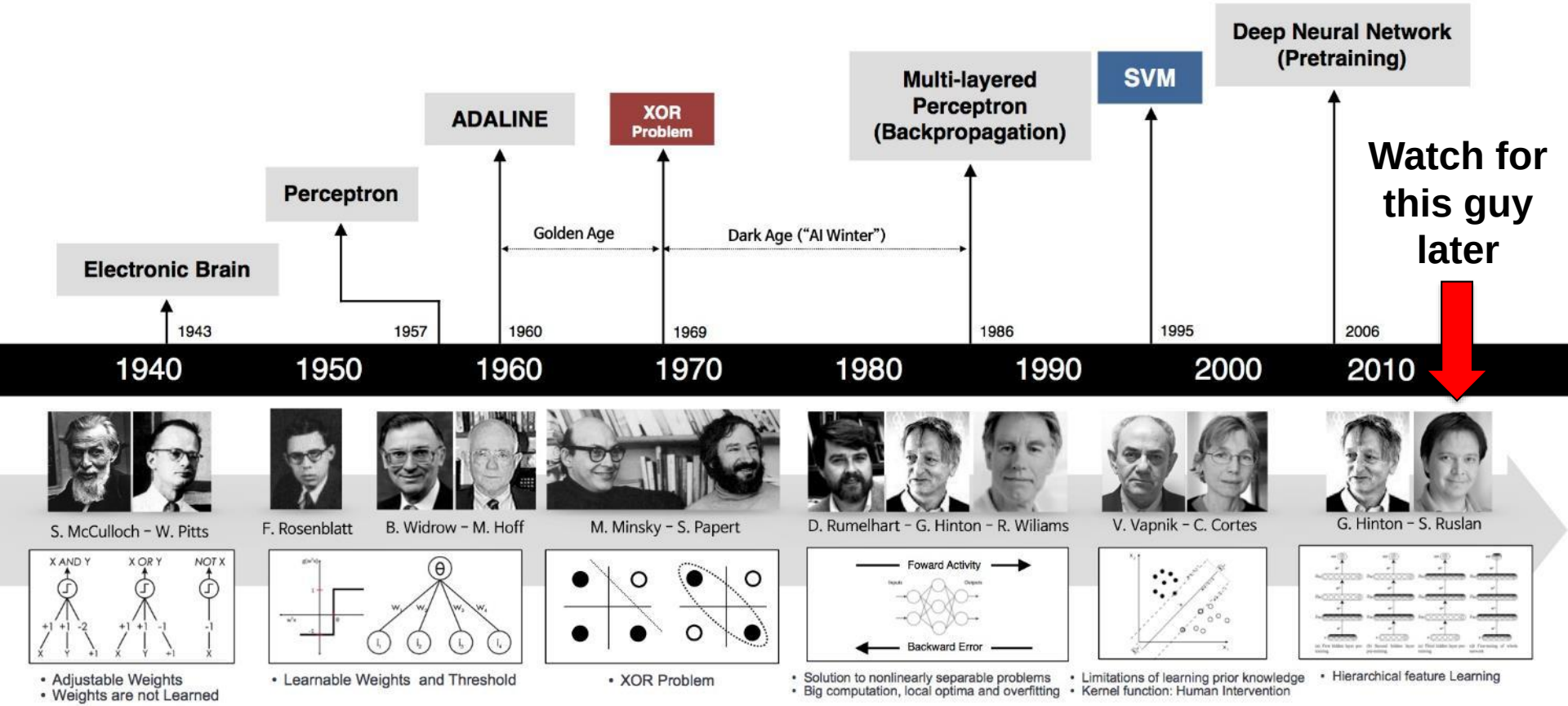
Understanding Technology Crutches

- It's critical to understand how **crutches** can and can't compensate for technology shortcomings
- E.g. failsafe remote teleop human intervention for AVs
  - Only viable in some applications
  - Critically reliant on system's ability for self-analysis

The Big One: Artificial Intelligence



123rf.com / efks

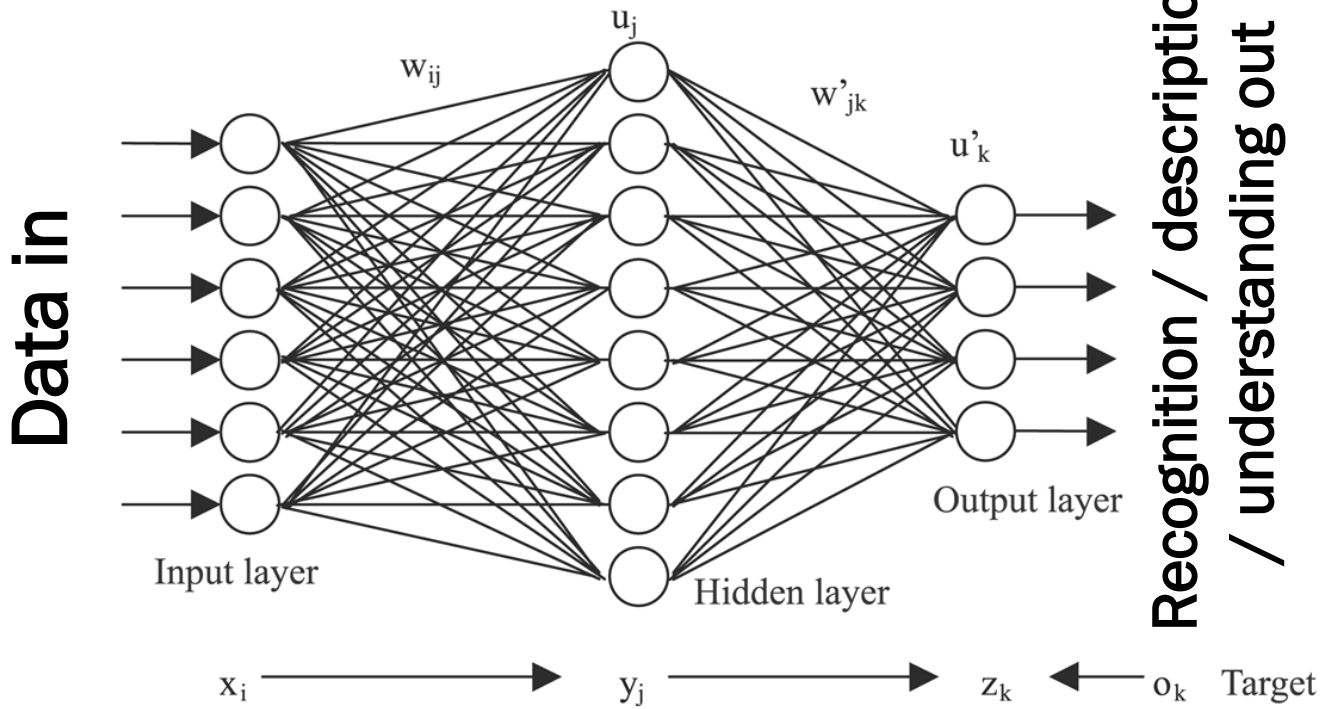


https://raw.githubusercontent.com/qingkaikong/blog/master/38_ANN_part1/figures/figure1_ANN_history.jpg

Modern Neural Network-based AI

Bio-inspired only in a very loose sense

Networks can have thousands of layers



http://www.extremetech.com/wp-content/uploads/2015/07/NeuralNetwork.png

Worth a lot of money

Worth a lot less money

Modern AI is Very Recent

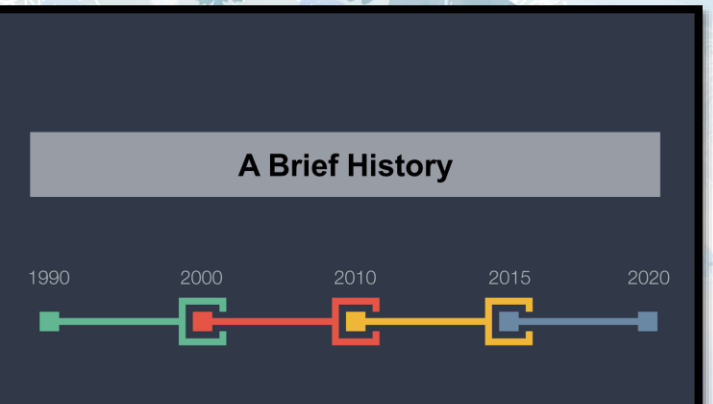
Multiple AI Winters

Hype cycle

Failure to deliver

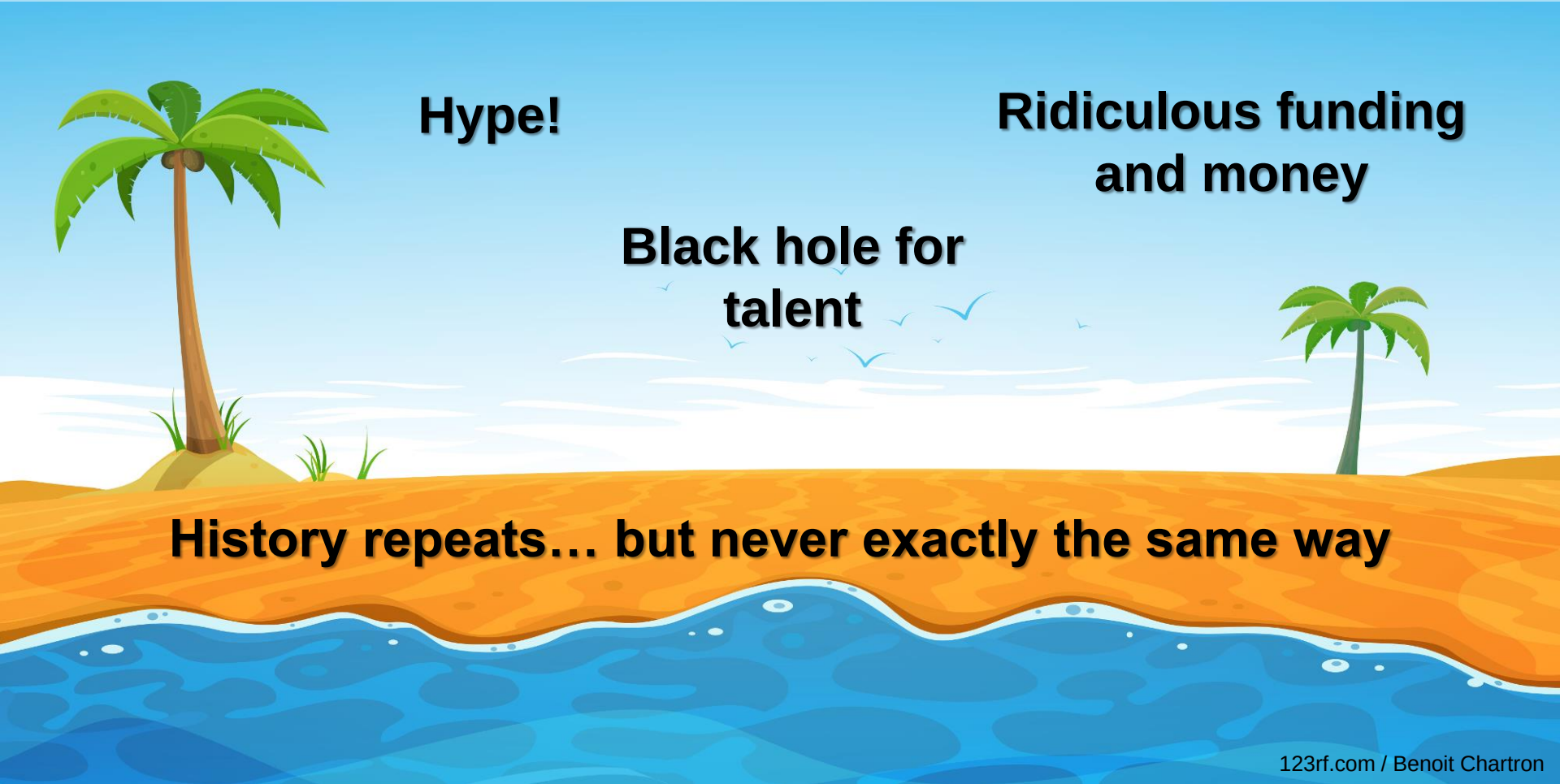
Reduced funding

Talent exodus



123rf.com / rvika

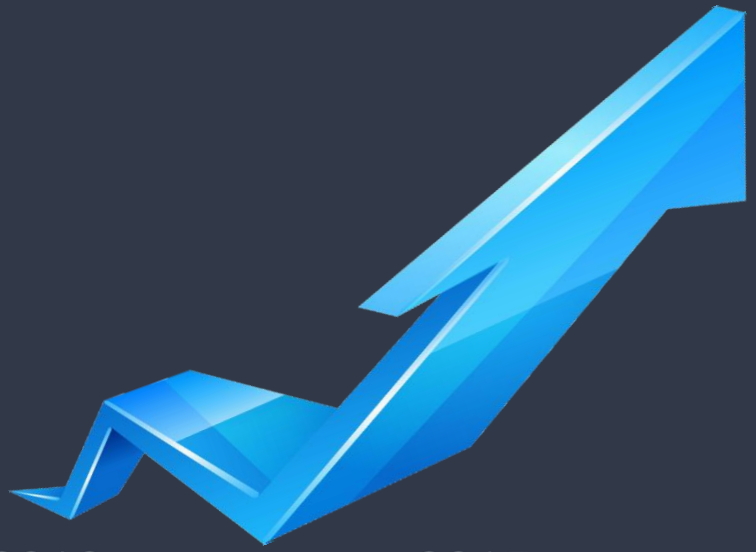
AI Summers?



123rf.com / Benoit Chartron

The “Comeback” – What’s Changed in the Past Decade?

1. Compute
2. Data

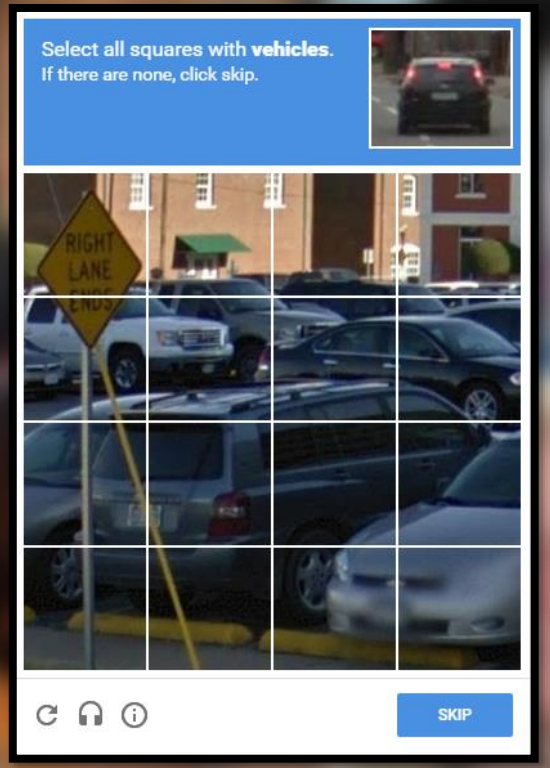


Scale of data available

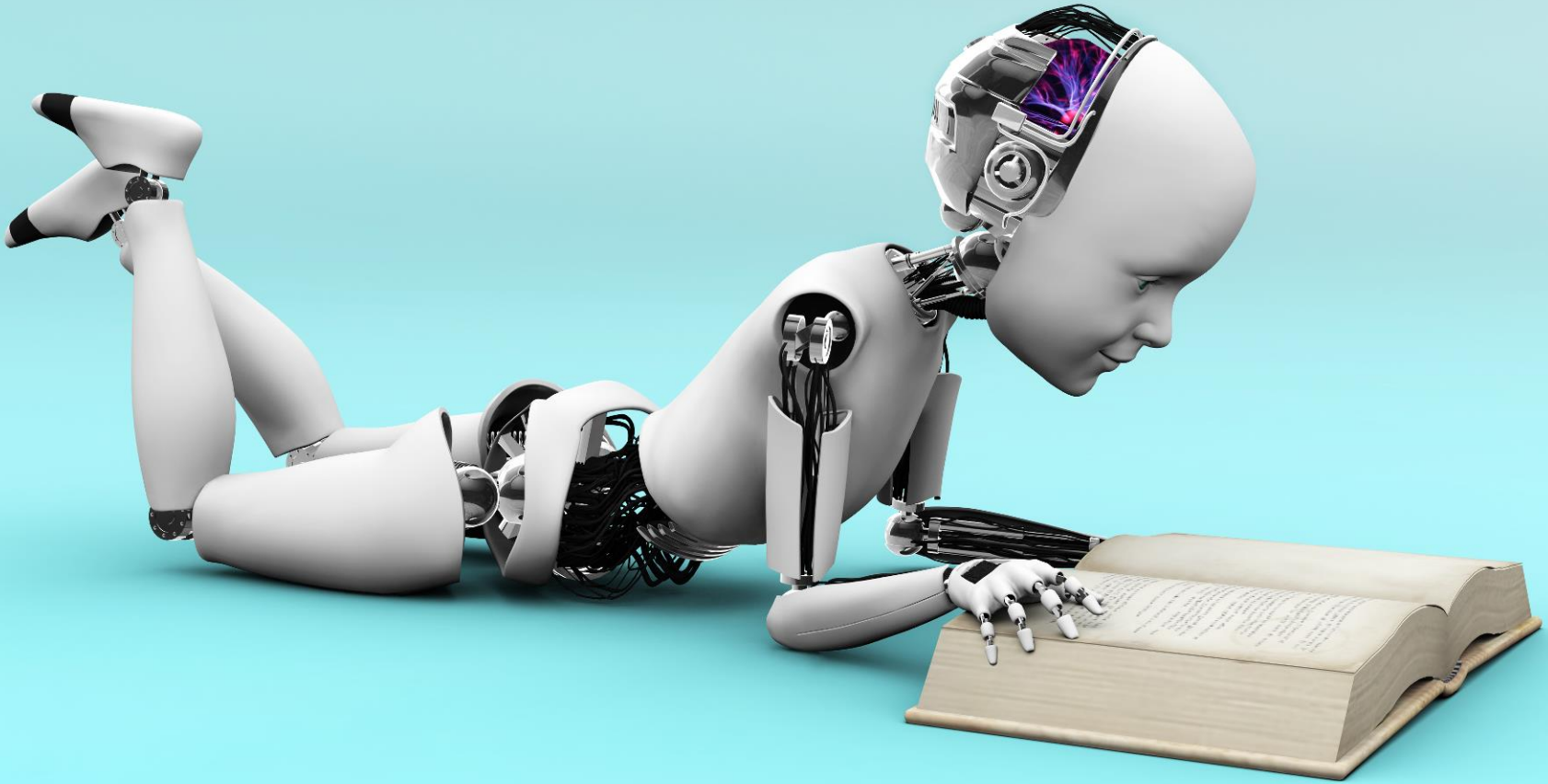
Michael

Ethan

Terese



Training AI Systems



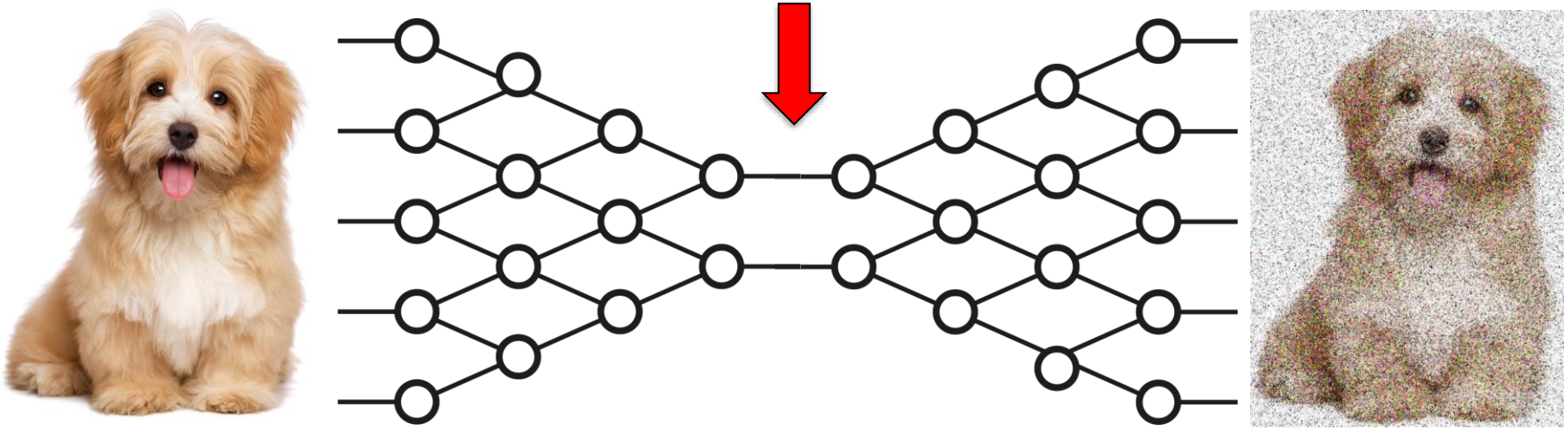
123rf.com / Sarah Holmlund

Supervised Learning

123rf.com / Danilo Sanino

Unsupervised Learning

Useful compact representations of data

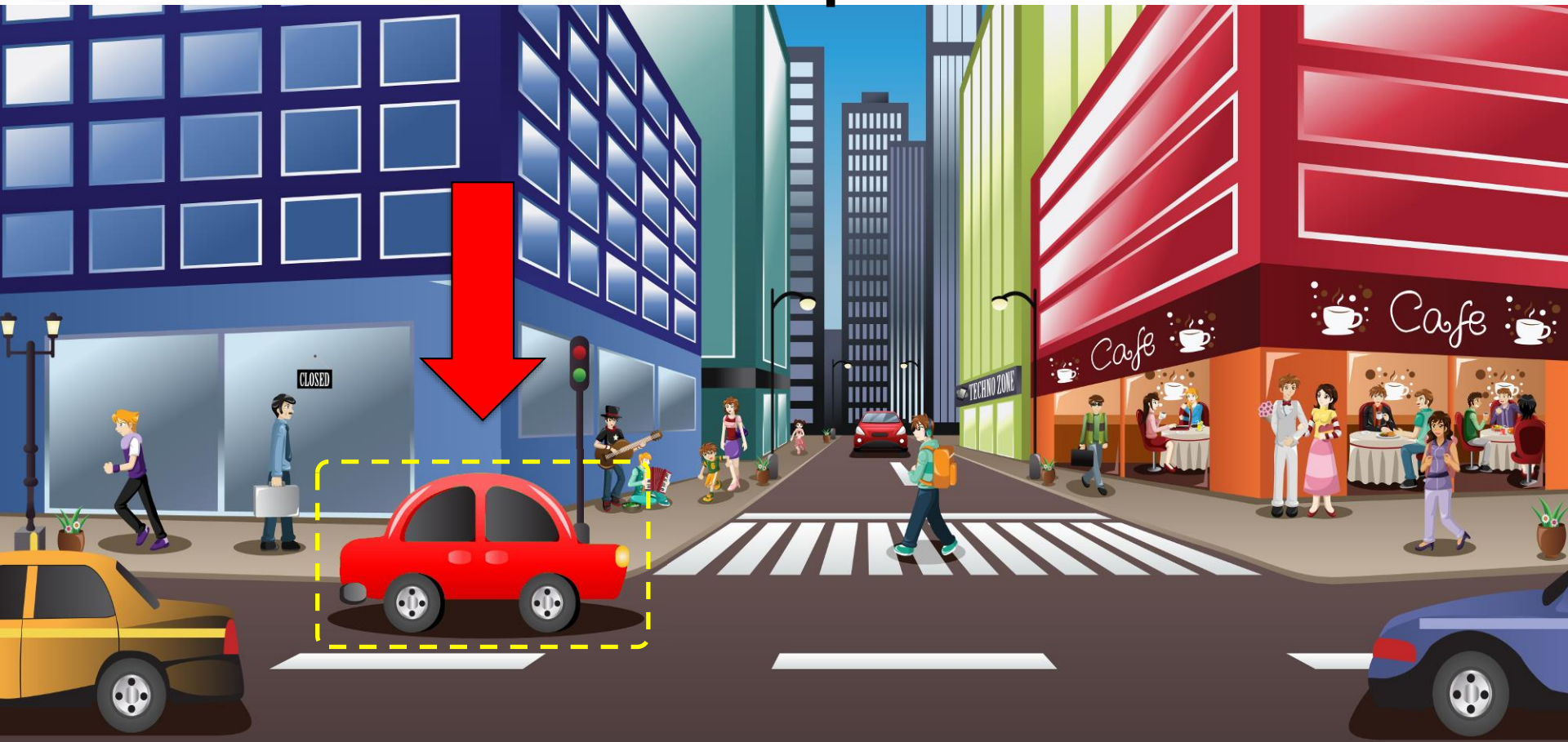


Key Data Concepts Discussed

- “Garbage in, garbage out”
- “Only as good as the data it’s trained on”
  1. It’s possible for AI systems to do far more with a certain source of data than a human can or could conceive of, **but**
  2. It’s also possible for AI systems to “cheat” outrageously and find the easiest way to solve an (often poorly formulated” problem

Understanding How You Know: An AI Fable

Understanding Systems through Input Manipulation



Looking Deep into the Network…

https://www.youtube.com/watch?v=dbQh1l_uvjo

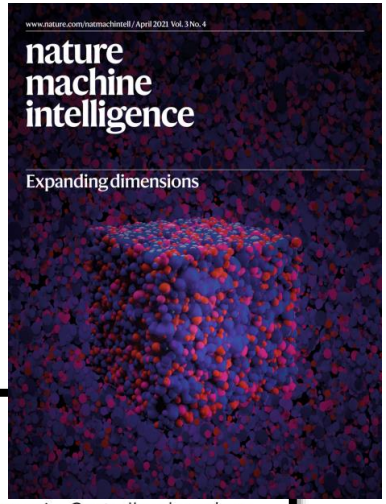
Small Networks are Directly Auditable

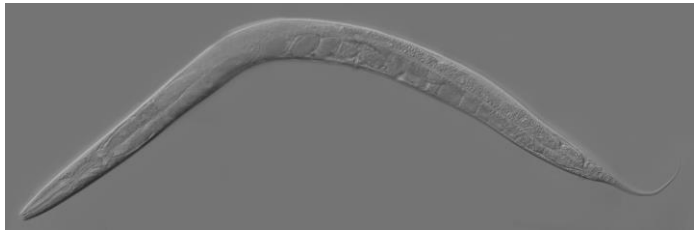
ARTICLES
https://doi.org/10.1038/s42256-020-00237-3
nature machine intelligence
Check for updates

Neural circuit policies enabling auditable autonomy

Mathias Lechner[1,4], Ramin Hasani[2,3,4], Alexander Amini[3], Thomas A. Henzinger[1], Daniela Rus[3] and Radu Grosu[2]

A central goal of artificial intelligence in high-stakes decision-making applications is taneously expresses generalizability by learning coherent representations of their wo dynamics. Here, we combine brain-inspired neural computation principles and scalab compact neural controllers for task-specific compartments of a full-stack autonomous a single algorithm with 19 control neurons, connecting 32 encapsulated input feature map high-dimensional inputs into steering commands. This system shows superior ge ness compared with orders-of-magnitude larger black-box learning systems. The ob autonomy for task-specific parts of a complex autonomous system.





By The original uploader was Kbradnam at English Wikipedia.(Original text: Zeynep F. Altun, Editor of www.wormatlas.org) - Transferred from en.wikipedia to Commons.(Original text: Donated by Zeynep F. Altun), CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=2680458

AUTONOMOUS SYSTEMS

C. Elegans inspires self-driving cars

Autonomous driving technology is improving, although doubts about their reliability remain. Controllers based on compact neural architectures could help improve their interpretability and robustness.

Michael Milford

If you had just woken up in late 2020 after a decade-long slumber, you might be forgiven for thinking that hardly any progress had been made in autonomous systems, given the lack of widespread applications such as on-road autonomous vehicles. Automation, it seems, is still struggling to escape from the domains where it has long been a staple of operation, including mines, logistics centres and marine ports. This relative lack of progress is all the more perplexing when we consider the apparent leaps and bounds of progress in the AI — and in particular, deep learning — research community. However, there are doubts about the generalizability

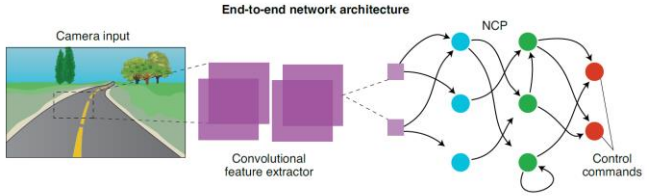


Fig. 1 | The visual input to control commands pipeline for a neural circuit policy network. The neural circuit policy network takes the latent representation of camera input produced by a convolutional neural network and transforms it into control commands for keeping the vehicle in its lane.

Compute Available

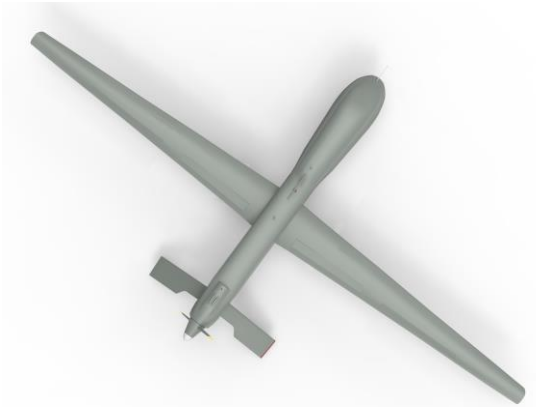
Compute:

https://images-na.ssl-images-amazon.com/images/I/818R7E0341L._SL1500_.jpg

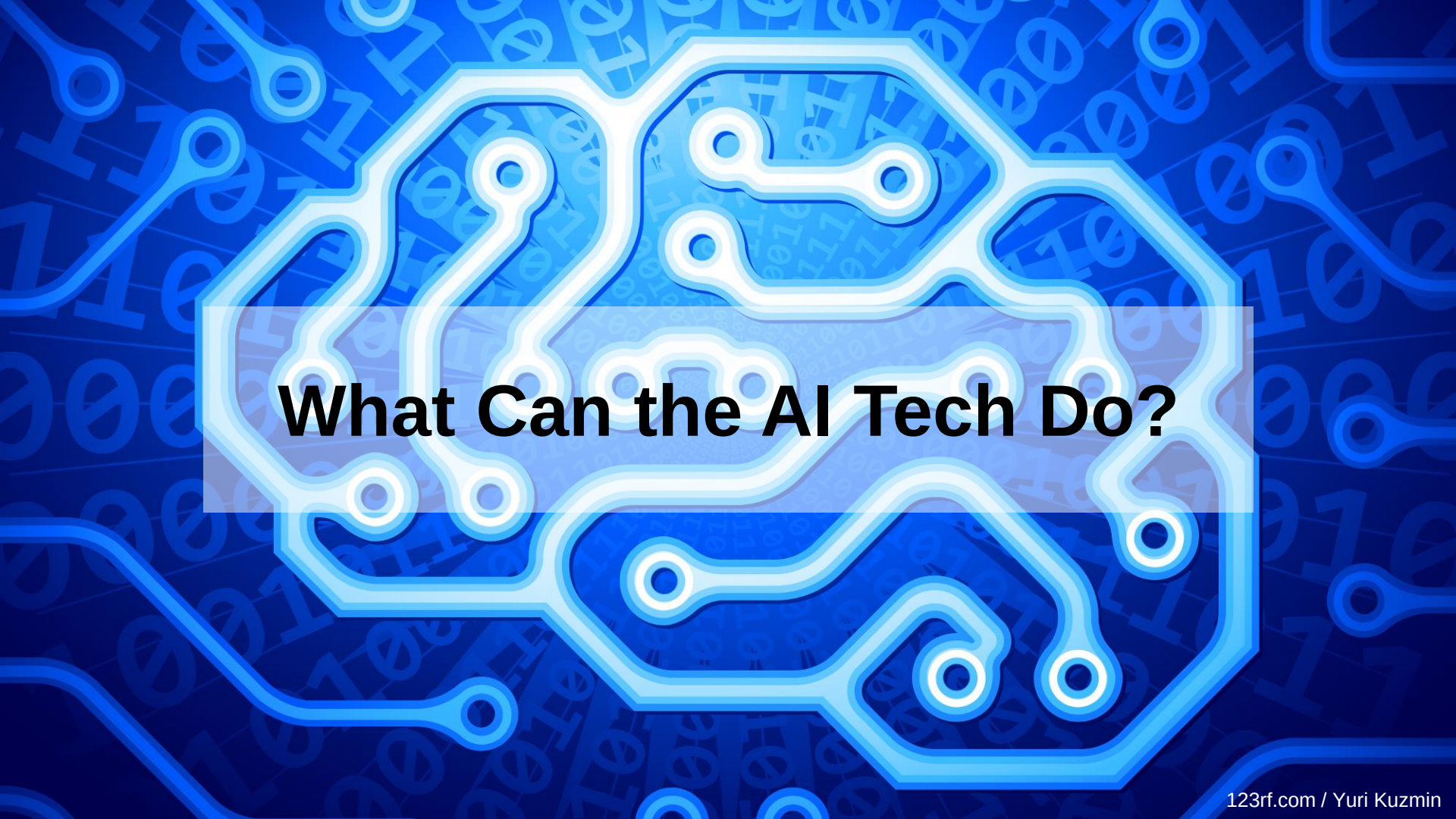
123rf.com / Maksym Shevchenko

Key compute concepts

- Online versus offline
- Training versus deployment
- On-board versus off-board (including “the cloud”)
- Although power hungry, compute is rarely the key power bottleneck in high mobility systems



What Can the AI Tech Do?



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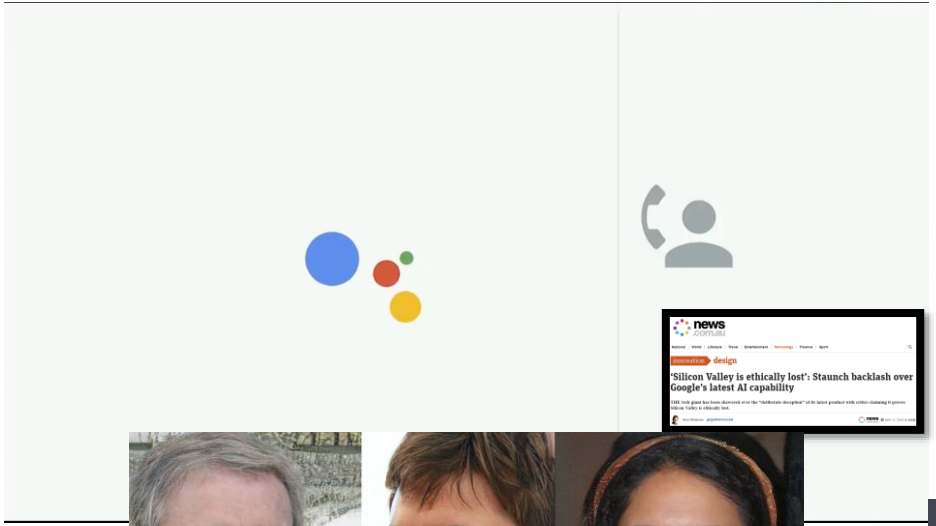
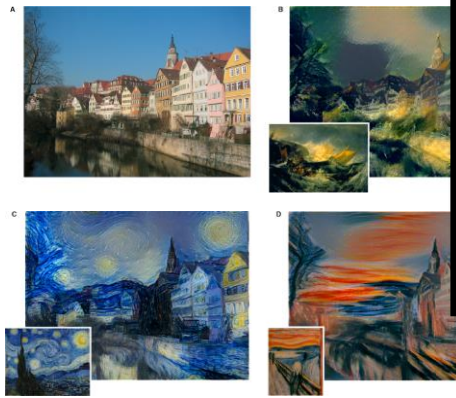
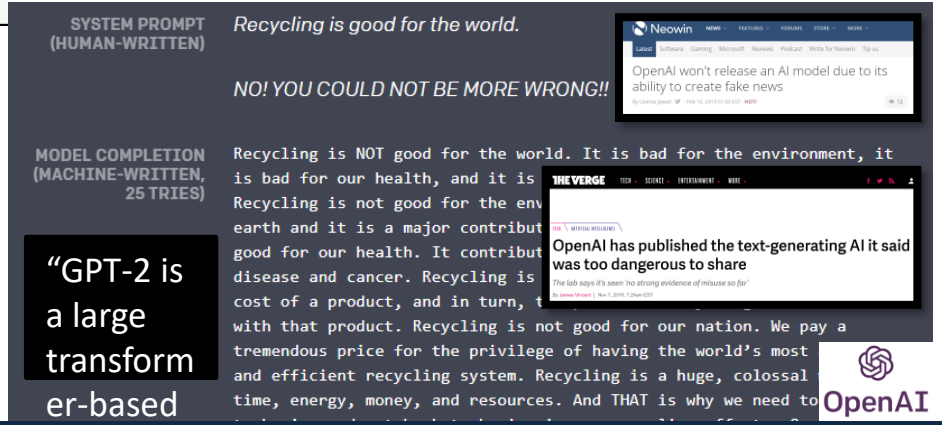
What Can the AI Tech Do?



https://www.vox.com/future-perfect/2019/5/31/18645993/ai-deepfakes-gan-explained-machine-learning



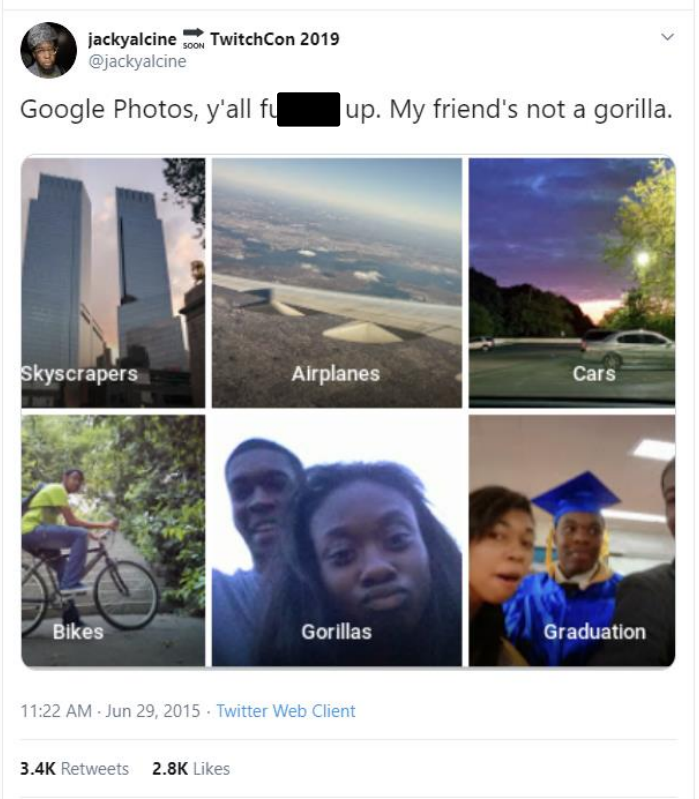
A Neural Algorithm of Artistic Style: https://arxiv.org/abs/1508.06576



Rule of Thumb: What Modern “AI” Can Do

- With enough attention and resources,
- you can develop modern AI-based technology that **matches** or **surpasses** human performance on most **constrained** tasks,
- **if** sufficient quantities of **representative** training data can be obtained, and
- **ideal performance can be defined.**

Only as good as what you feed it



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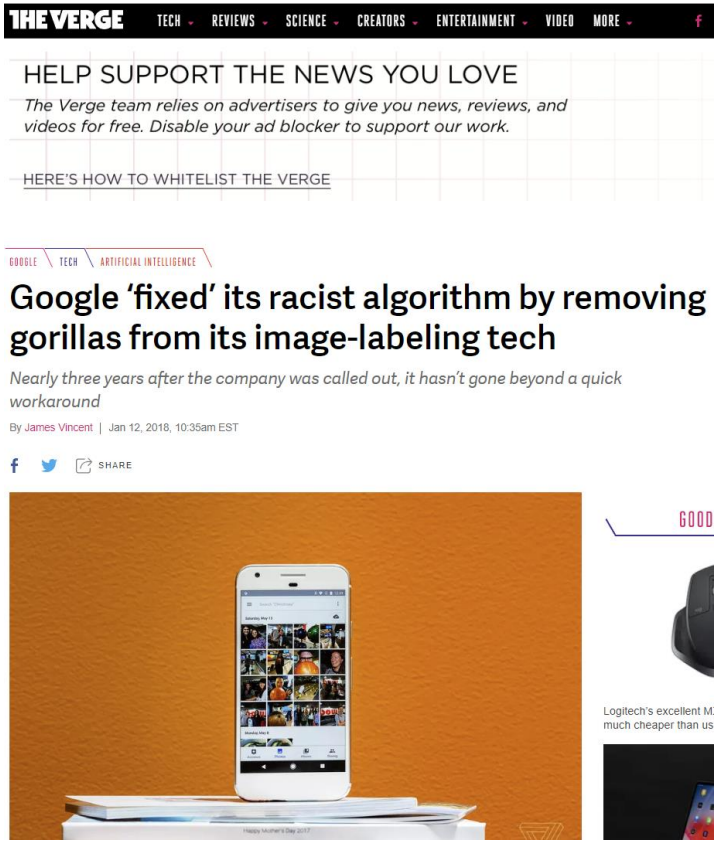


Key Concept

Unintuitive behaviour

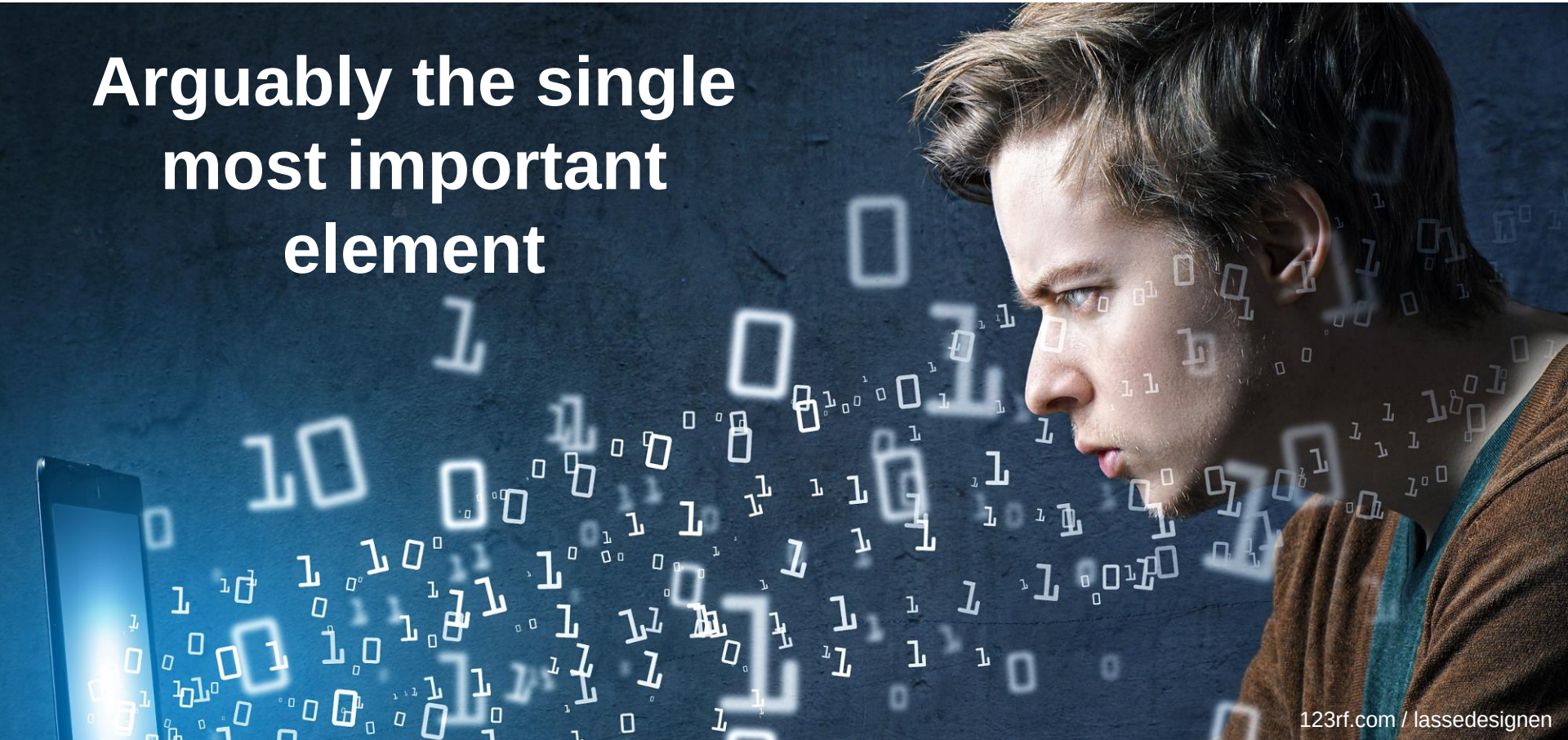
Incredible Resources Being Brought to Bear on Solving These Problems

Szegedy et al, “Intriguing properties of neural networks”, https://arxiv.org/abs/1312.6199

Talking About Expertise…

123rf.com / Olivier Le Moal

Talent and Expertise

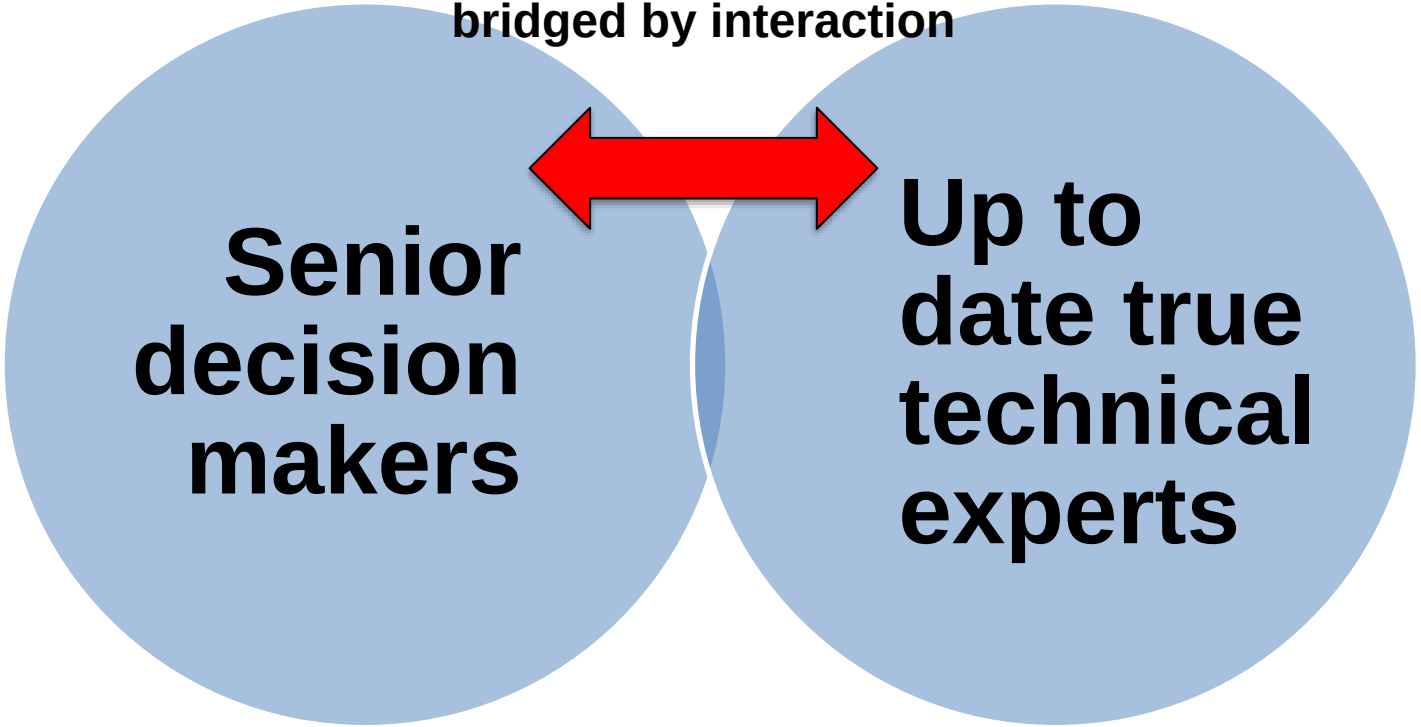


2018 Conference on Robot Learning, Zurich

“Representative Industry/Commercial Sector Event”

Never the twain shall meet… *Rudyard Kipling*

Gap inefficiently bridged by interaction



Beware Technical Lightweights

- Much of the key tech is very recent so only otherwise inexperienced juniors are familiar
- "Senior" staff (**Professors**, **Futurists**, **C Level Executives** etc…) who haven't made a significant effort to continuously retrain will lack **DEEP** technical understanding

123rf.com / Amikishiyev

The Partial Illusion of Democratization

- Increasing availability of packages and tools fosters the partial **illusion** of democratized AI and tech **BUT**
- Reality is that **mechanistic use of these tools is very different to mastery**
- Mastery often requires access to a still highly limited “**top talent**” pool, **proprietary data** and **incredible compute**.

123rf.com / destinacigdem

An Incredible Landscape for Talent in the Field

Known as “Funny Money” in the industry

allure Network

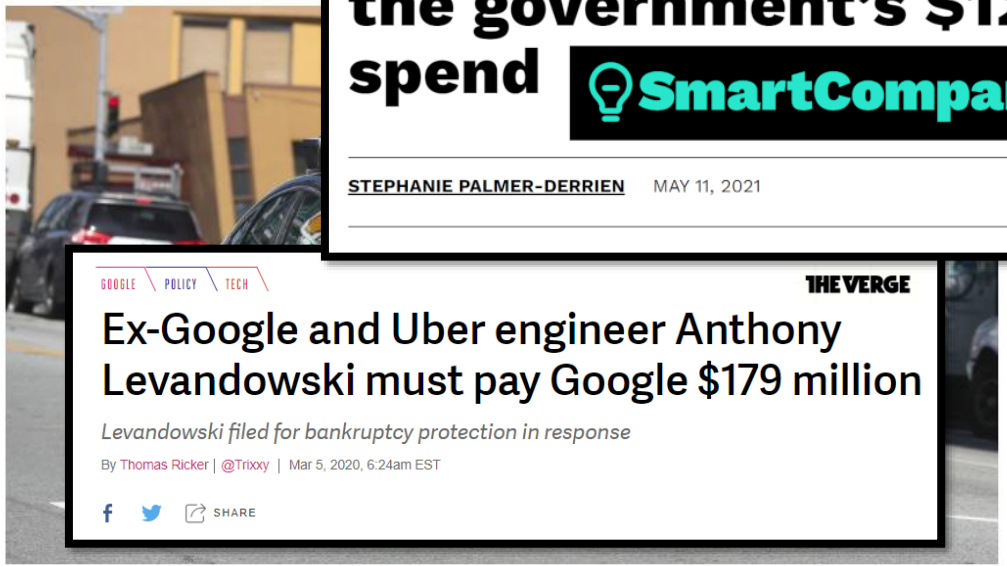
GIZMODO AU

ile Car Tech Online Science & Health Cameras Computing Gaming Entertainment

Uber Reveals [redacted] Bonus Dispute Between Fired Engineer And Google

Kate Conger

Jun 29, 2017, 9:00am· Filed to: anth

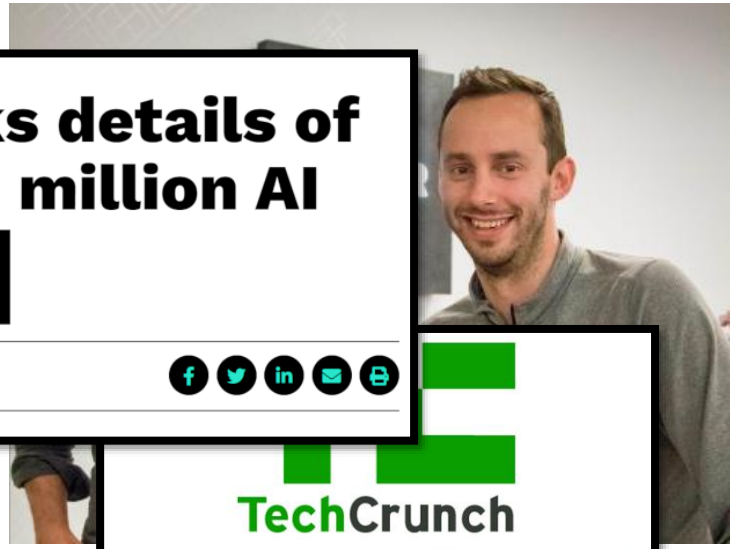


FEDERAL BUDGET 2021, TECHNOLOGY

Federal budget unpacks details of the government’s $124 million AI spend

SmartCompany

STEPHANIE PALMER-DERRIEN MAY 11, 2021



GOOGLE \ POLICY \ TECH

THE VERGE

Ex-Google and Uber engineer Anthony Levandowski must pay Google $179 million

Levandowski filed for bankruptcy protection in response

By Thomas Ricker | @Trixxy | Mar 5, 2020, 6:24am EST

SHARE

TechCrunch

Waymo case reveals Levandowski got $250 million in Uber stock for Otto

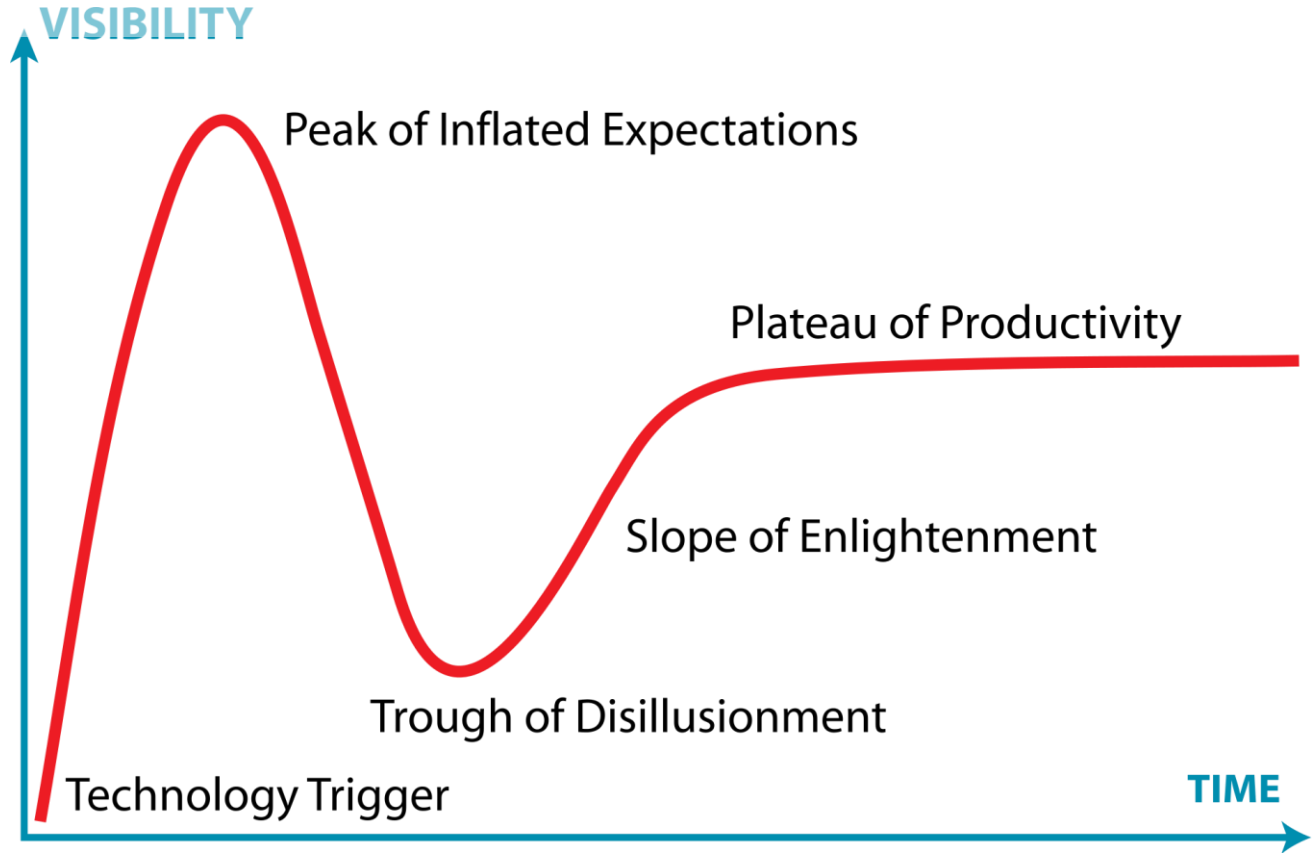
otics

Predicting and Planning for the Future

123rf.com / Katarzyna Białasiewicz

Key Concept

The Classic Hype Cycle Implicitly Assumes Eventual Success



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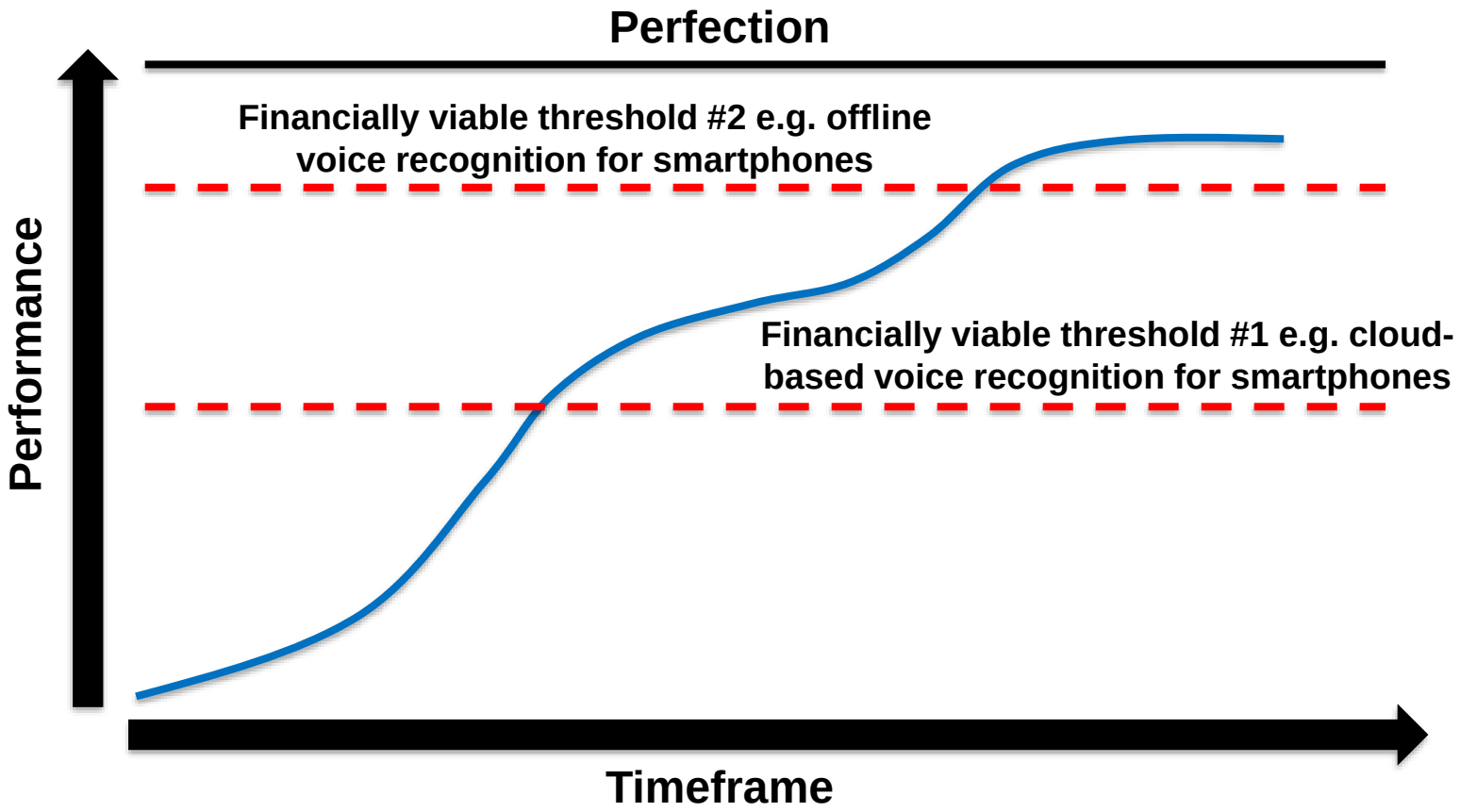
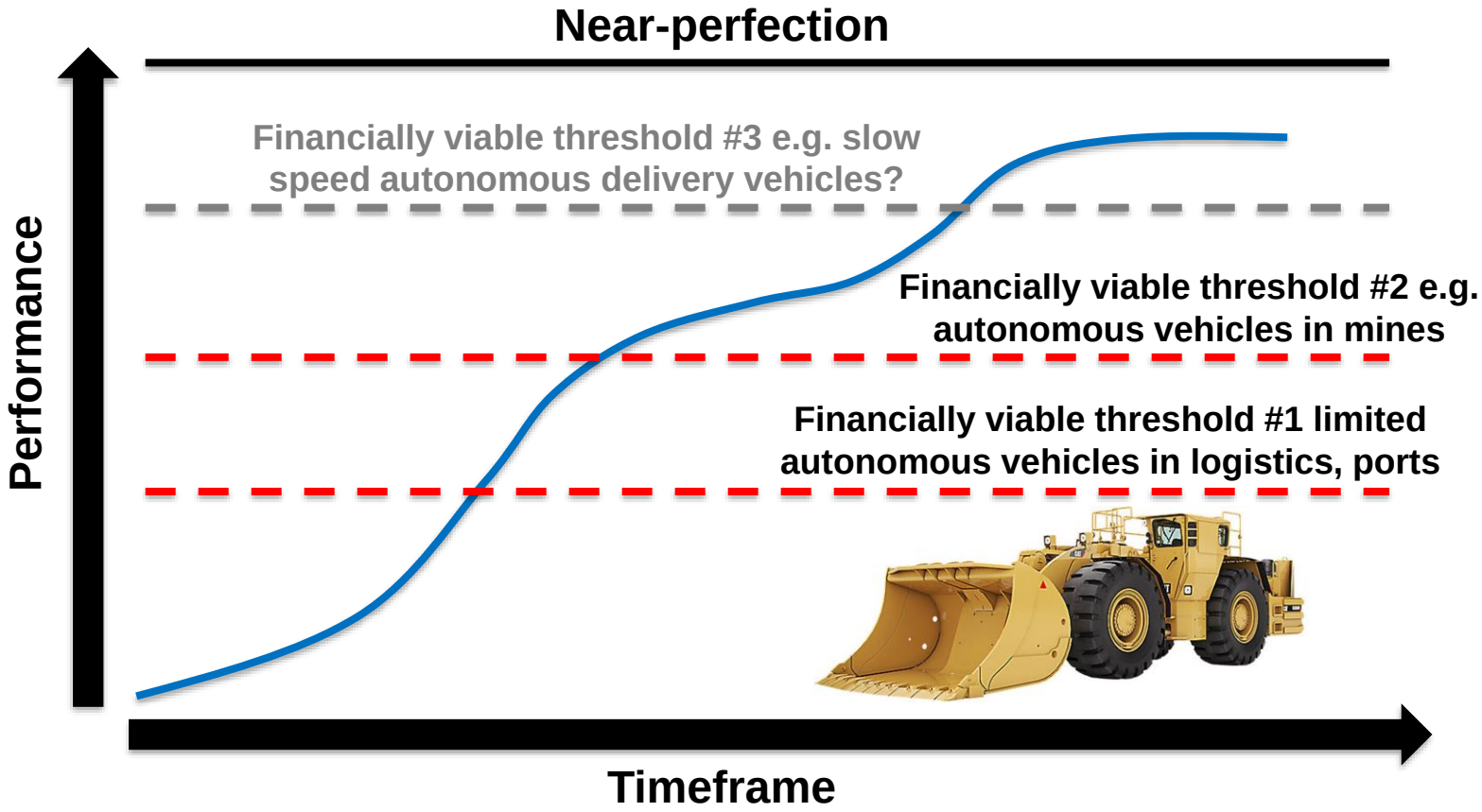
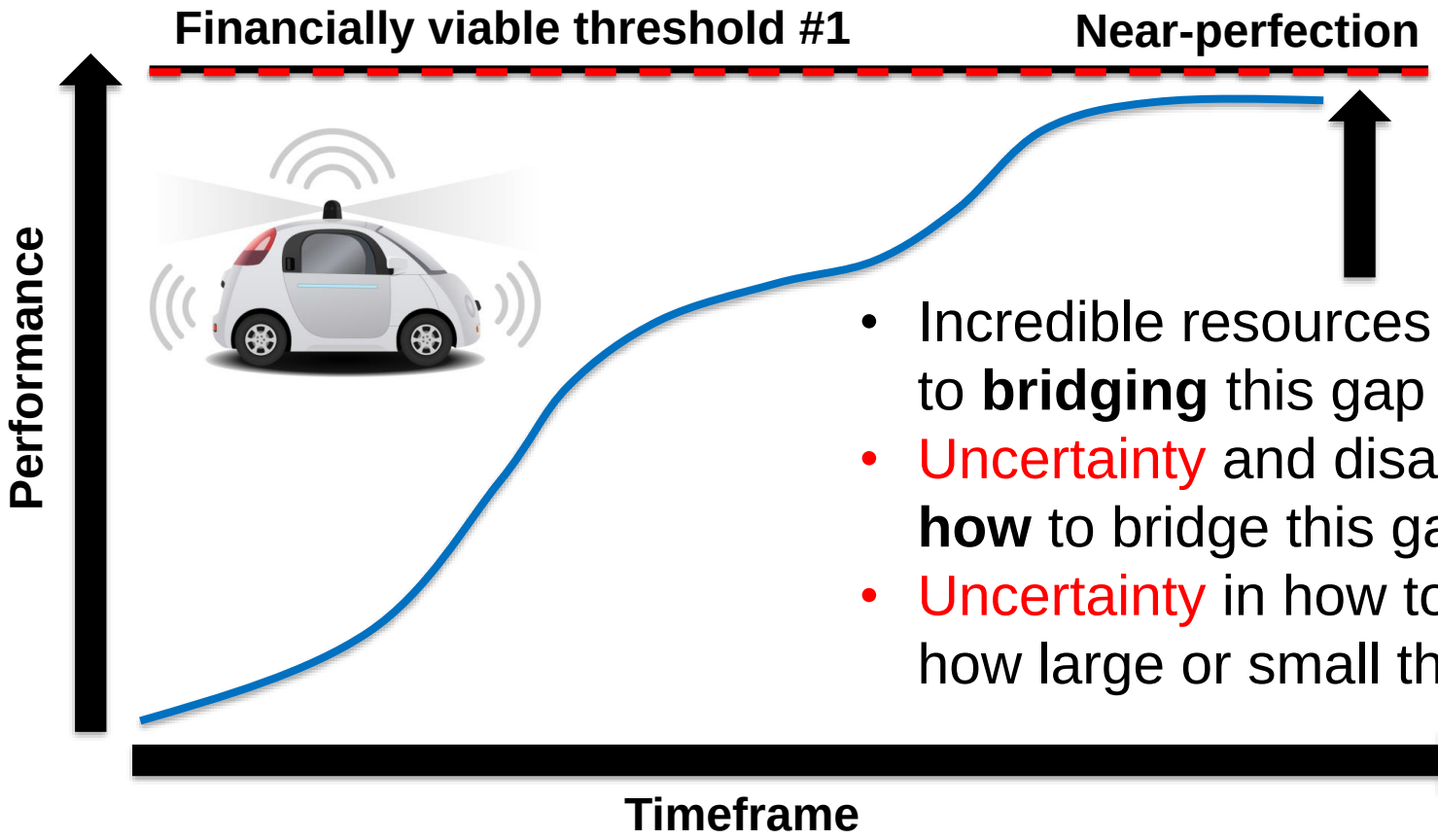
Progress Charts – Typical Technology



Progress Charts – General AV Technology



Progress Charts – Widespread, Passenger-Carrying Robotaxis



- Incredible resources devoted to **bridging** this gap
- Uncertainty and disagreement **how** to bridge this gap
- Uncertainty in how to **assess** how large or small this gap is!

Key Takeaways

My Recommendations About These Technologies

Avoid the temptation to think in unchanging absolutes about the technology e.g. “never be like a human”, “solves everything”

See through the hype but don’t dismiss everything out of hand (this requires nuance)

Keep an informed, regularly updated awareness of the range of scenarios that could play out

Future Technologies of War

Robotics, AI and Autonomy: Moving Beyond The Hype to a Deeper Understanding

Professor Michael Milford
Acting Director
QUT Centre for Robotics

QUT Centre for Robotics

123rf.com / Jesse-lee Lang