Trusted and Introspective Positioning Systems for People and their Machines

IROS2024 Workshop on

Long-Term Perception for Autonomy in Dynamic Human-shared Environments: What Do Robots Need?

Monday, October 14, 2024

Abu Dhabi, UAE

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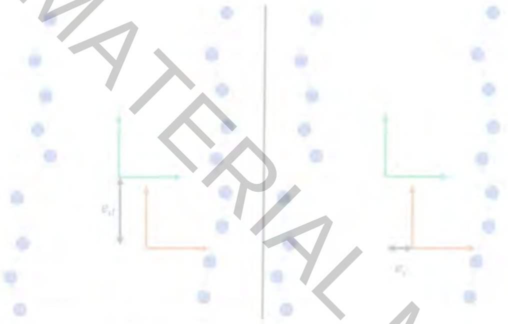
http://www.tinyurl.com/milfordm
https://goo.gl/rczsle

QUT Centre for Robotics

Overview

Introductions

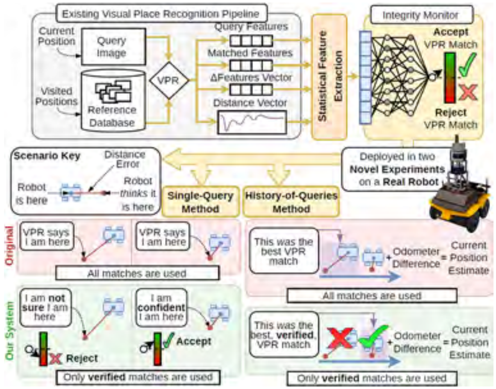


1) All Errors are Not Equal

Nordland		
R@1	R@5	R@10
42.9	49.2	51.6
42.4	48.8	51.2
44.5	50.1	52.0
44.9	50.2	52.2

2) We Need Better Metrics

3) The Incredible Power of Introspection



4) Resilience to Adversity and Adversarial Interference

5) Human Factors: Privacy, Sustainability

Final Thoughts

Introduction to the QUT Centre for Robotics

Fundamental and Applied Research on Robots and Autonomous Platforms

Aerospace | Environment | Manufacturing | Defence | Agriculture | Mining | Medical | Infrastructure | Logistics

Air

Land

Water

Major Centres and Projects

QUT Centre for Robotics

Australian Cobotics Centre

ARIAM Australian Robotic Inspection and Asset Management Hub

Australian Research Council Training Centre for Automated Vehicles in Rural and Remote Regions

Joint Biomechanics Training Centre

SAEF Securing Antarctica's Environmental Future

ARM Advanced Robotics for Manufacturing HUB

Australia-US International Multidisciplinary University Research Initiative (AUSMURI)

Australian Research Council Laureate Fellowship

Australian Government Australian Research Council

2014-20 Headquarters of the Australian Centre for Robotic Vision

Education, Outreach and Expert Advising

Fellows of Learned Academies and Bodies

Australian Academy of Science

IEEE

Board Roles

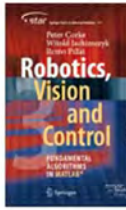
Australian Government Civil Aviation Safety Authority

MTA Institute

ATSE Australian Academy of Technology & Engineering

Bachelor of Engineering (Honours) (Mechatronics)

Master of Robotics and Artificial Intelligence



ROBOT ACADEMY

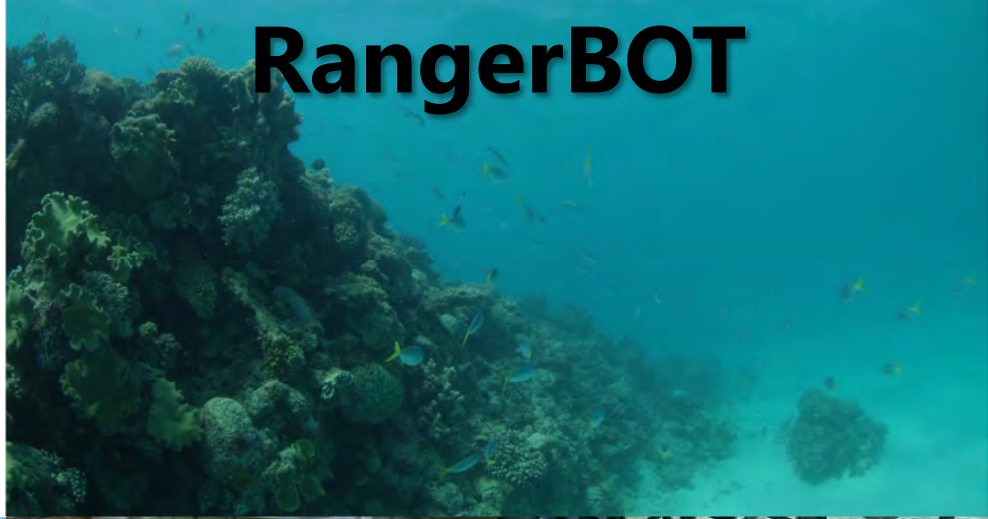
Math Thrills

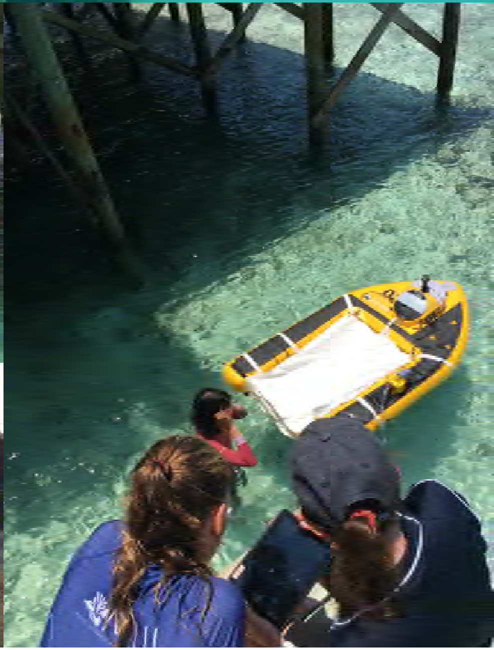
Flagship Projects Taster

COTSBot

RangerBOT

Dunbabin, Mou, Tsai and many colleagues, collaborators and funders





Dayoub, F., Dunbabin, M., & Corke, P. (2015). **Robotic detection and tracking of crown-of-thorns starfish**. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*.

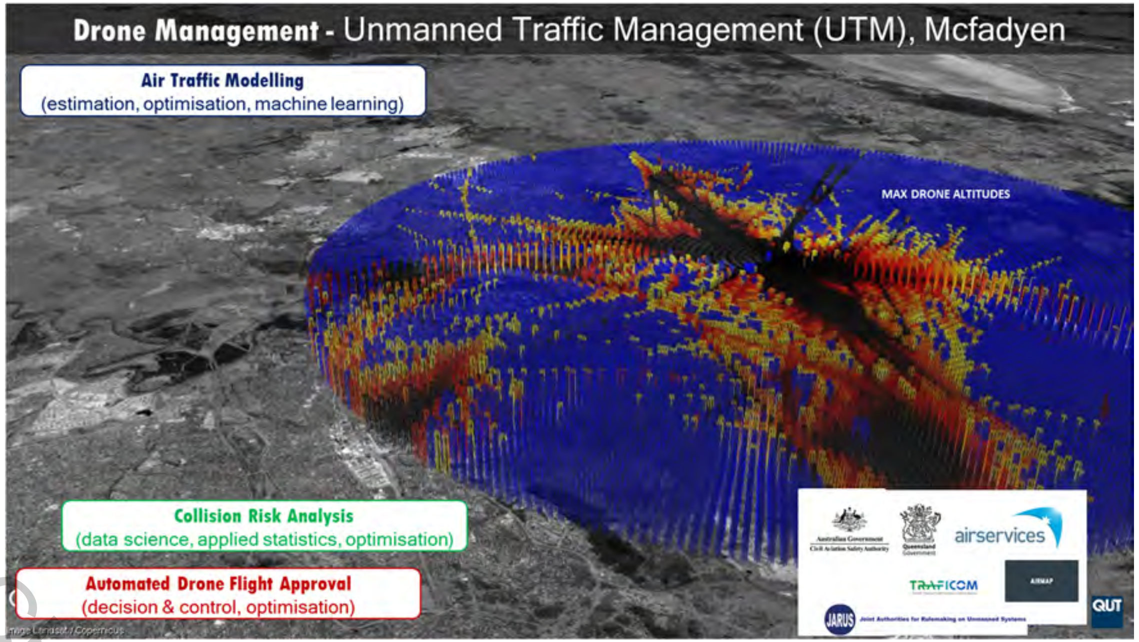
Google Impact Challenge

Great Barrier Reef Foundation

QUT ife Institute for Future Environments

SAEF
Securing Antarctica's Environmental Future
Australian Research Council Special Research Initiative

Prof Felipe Gonzalez, Julian Galvez-Serna, Juan Sandino and many more



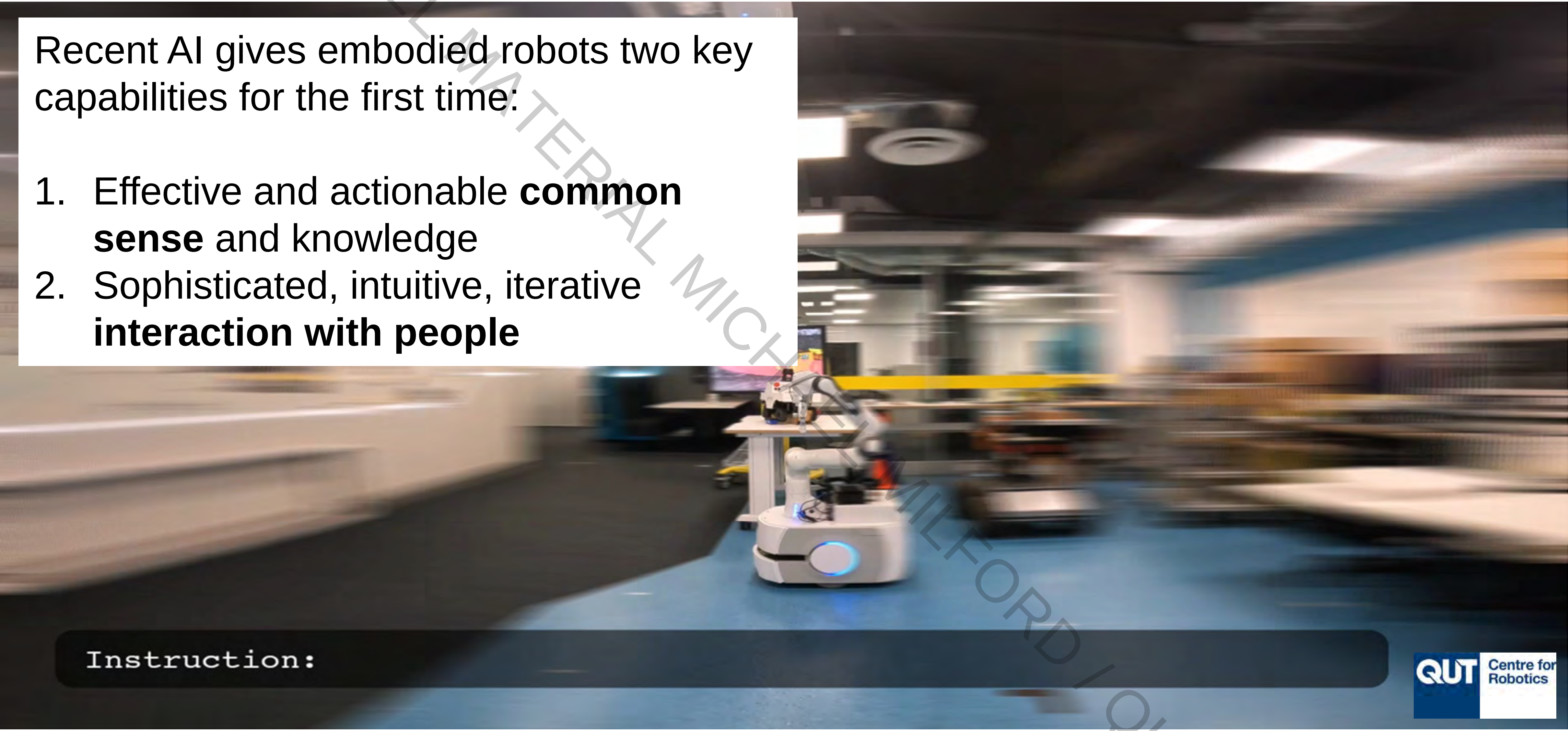
McFadyen and many colleagues, collaborators and funders

Yandiwanba: Lunar Space Testing Facility

Entering the Physical World: Large Language Models and Robotics

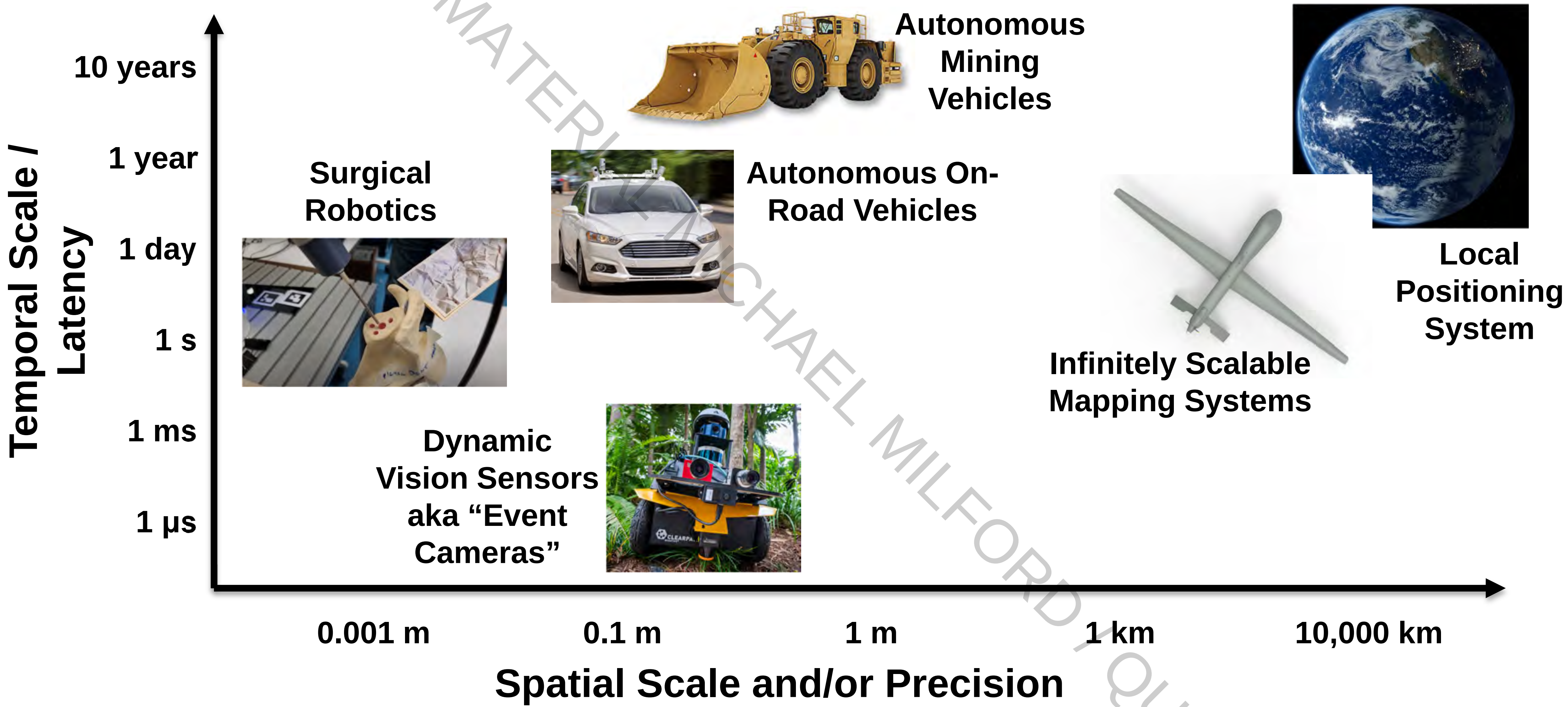
Recent AI gives embodied robots two key capabilities for the first time:

1. Effective and actionable **common sense** and knowledge
2. Sophisticated, intuitive, iterative **interaction with people**



Rana, K., Haviland, J., Garg, S., Abou-Chakra, J., Reid, I.D., & Sünderhauf, N., "SayPlan: Grounding Large Language Models using 3D Scene Graphs for Scalable Task Planning.", in *Conference on Robot Learning*, 2023

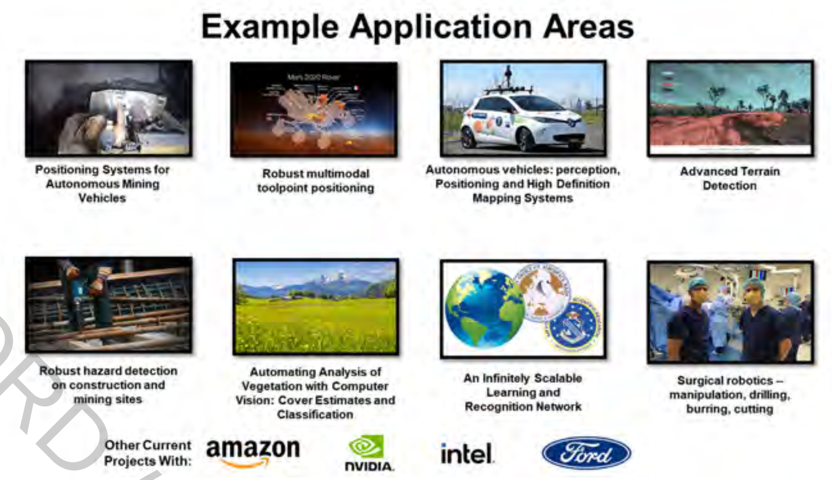
Positioning for Autonomy: Scaling up in Time and Space



PART 2: Reflections on How We Conduct Localization Research in Robotics, Computer Vision, Machine Learning and Autonomous Vehicles

Reflections on How We Conduct Research: Motivated in the Context of Enduring Autonomy and Localization

1. All errors are **not equal**
2. Conventional metrics are often **not strongly predictive** of actual deployment utility
3. For operationally critical, human supervised or collaborative tasks, **introspective capability trumps** just about everything else



Positioning Systems for Autonomous Vehicles

QUT & Ford Motor Corporation

PAPER HIGHLIGHTS

S Hausler, M Xu, S Garg, P Chakravarty, S Shrivastava, A Vora, M Milford, “Improving worst case visual localization coverage via place-specific sub-selection in multi-camera systems”, in *IEEE Robotics and Automation Letters, 7 (4), 2022*

S Hausler, S Garg, P Chakravarty, S Shrivastava, A Vora, M Milford, “Locking On: Leveraging Dynamic Vehicle-Imposed Motion Constraints to Improve Visual Localization”, in *IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2023

S Hausler, S Garg, P Chakravarty, S Shrivastava, A Vora, M Milford, “DisPlacing Objects: Improving Dynamic Vehicle Detection via Visual Place Recognition under Adverse Conditions”, in *IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2023

QUT Centre for Robotics

Reminder About the Dominant Metrics

Table 2. Ablation study

Method	Nordland			Mapillary (Val. set)			Pittsburgh 30k			Tokyo 24/7			RobotCar Seasons v2			Extended CMU Seasons		
	R@1	R@5	R@10	R@1	R@5	R@10	R@1	R@5	R@10	R@1	R@5	R@10	.25m/2°	.5m/5°	5.0m/10°	.25m/2°	.5m/5°	5.0m/10°
Ours (Single-Spatial-Patch-NetVLAD)	42.9	49.2	51.6	77.2	85.4	87.3	88.0	94.0	95.6	78.1	83.8	87.0	8.7	32.4	88.4	10.0	31.5	95.2
Ours (Single-RANSAC-Patch-NetVLAD)	42.4	48.8	51.2	77.8	85.7	**87.8**	87.3	94.2	95.7	82.2	87.3	89.2	8.7	31.6	88.3	10.0	31.3	94.5
Ours (Multi-Spatial-Patch-NetVLAD)	44.5	50.1	52.0	78.2	85.3	86.9	88.6	**94.5**	95.8	81.9	85.7	87.9	9.4	33.9	89.3	11.1	34.5	**96.3**
Ours (Multi-RANSAC-Patch-NetVLAD)	**44.9**	**50.2**	**52.2**	**79.5**	**86.2**	87.7	**88.7**	**94.5**	**95.9**	**86.0**	**88.6**	**90.5**	**9.6**	**35.3**	**90.9**	**11.8**	**36.2**	96.2

Method	Nordland			Extended CMU Seasons		
	R@1	R@5	R@10	.25m/2°	.5m/5°	5.0m/10°
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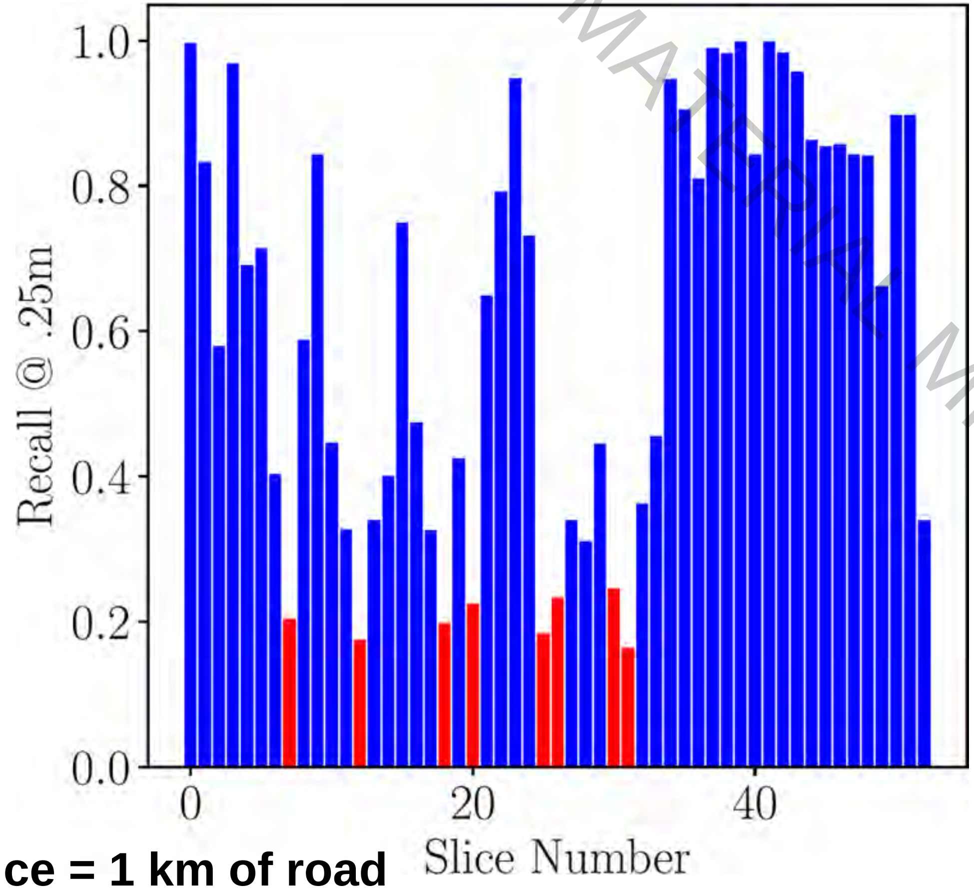
Hausler, Stephen; Garg, Sourav; Xu, Ming; Milford, Michael; Fischer, Tobias, "Patch-NetVLAD: Multi-Scale Fusion of Locally-Global Descriptors for Place Recognition", in *Conference on Computer Vision and Pattern Recognition*, 2021.

Autonomous On-Road Vehicles



Slice = 1 km of road

- System / model changes that assist with deployability (e.g. worst case localization coverage) can be **invisible** to conventional performance metrics

Method	Nordland			Extended CMU Seasons		
	R@1	R@5	R@10	.25m/2°	.5m/5°	5.0m/10°
Ours (Single-Spatial-Patch-NetVLAD)	42.9	49.2	51.6	10.0	31.5	95.2
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- H Carson, JJ Ford, M Milford, “Unsupervised Localization Quality Prediction for Improved Single-Frame and Weighted Sequential Visual Place Recognition”, *IEEE International Conference on Robotics and Automation*, 2023
- H Carson, JJ Ford, M Milford, “Predicting to Improve: Integrity Measures for Assessing Visual Localization Performance”, *IEEE Robotics and Automation Letters 7 (4)*, 2022

Localization Coverage Scenario 1

PAPER HIGHLIGHTS

Hausler, Stephen; Garg, Sourav; Xu, Ming; Milford, Michael; Fischer, Tobias, “Patch-NetVLAD: Multi-Scale Fusion of Locally-Global Descriptors for Place Recognition”, in *Conference on Computer Vision and Pattern Recognition*, 2021.

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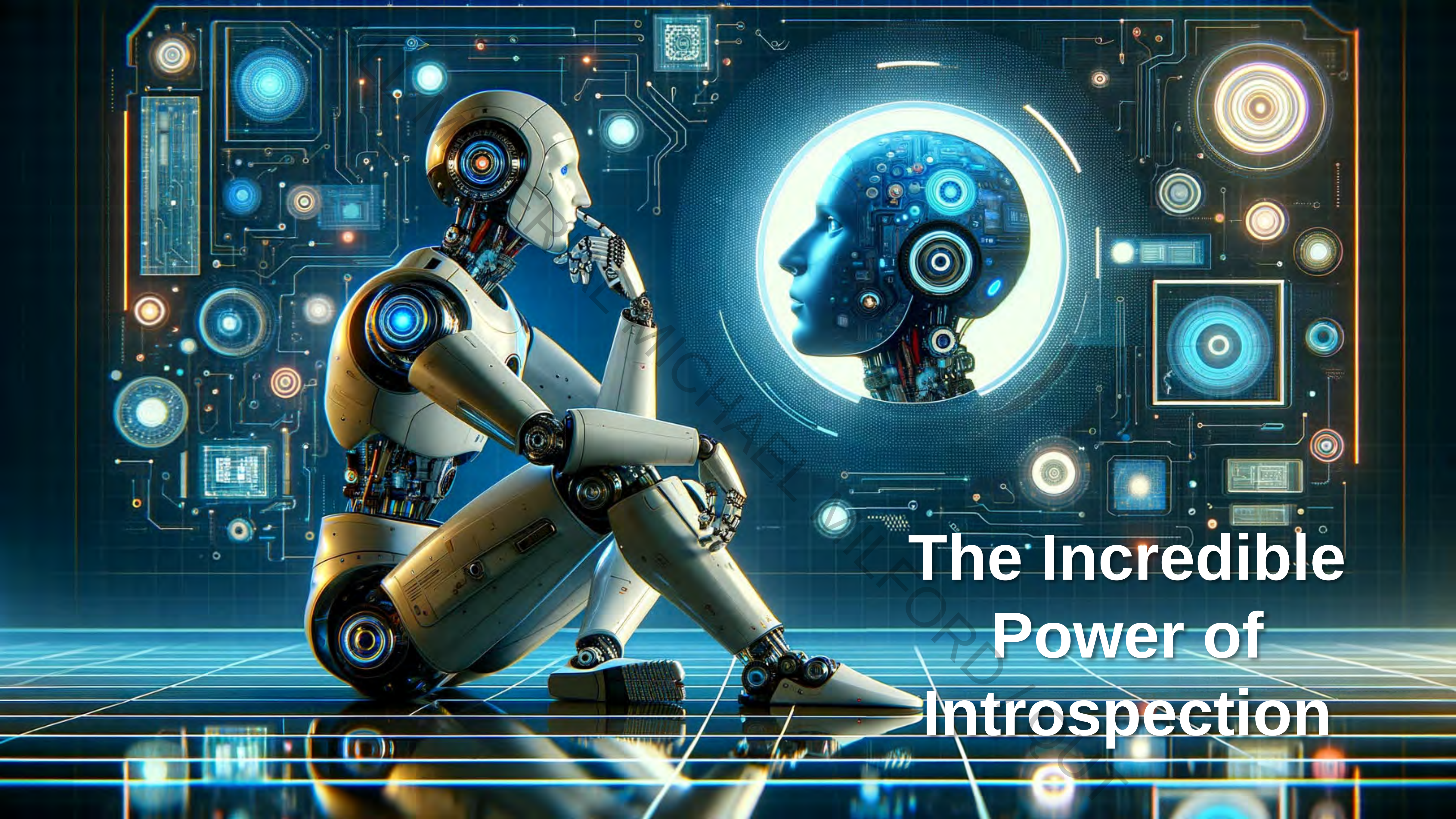
Localization Coverage Scenario 2

PAPER HIGHLIGHTS

Hausler, Stephen; Garg, Sourav; Xu, Ming; Milford, Michael; Fischer, Tobias, “Patch-NetVLAD: Multi-Scale Fusion of Locally-Global Descriptors for Place Recognition”, in *Conference on Computer Vision and Pattern Recognition*, 2021.

Performance metrics should be better connected to the actual deployment context.


The Incredible
Power of
Introspection

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 very challenging to create.**

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Positioning Integrity

Helen Carson

‘Characterisability’

Auditability

Trust

Provability

Guaranteed Performance Bounds

PAPER HIGHLIGHTS

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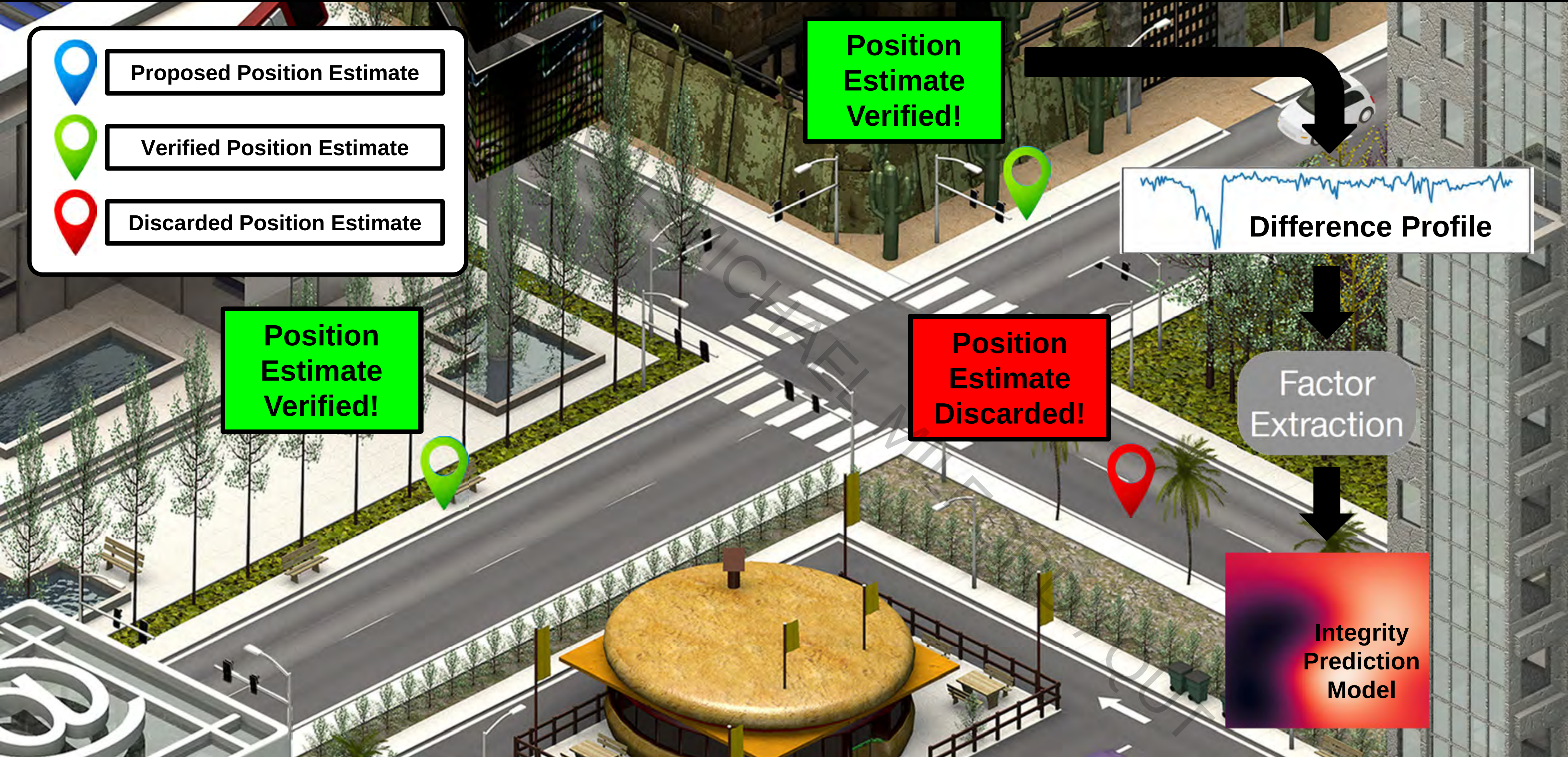
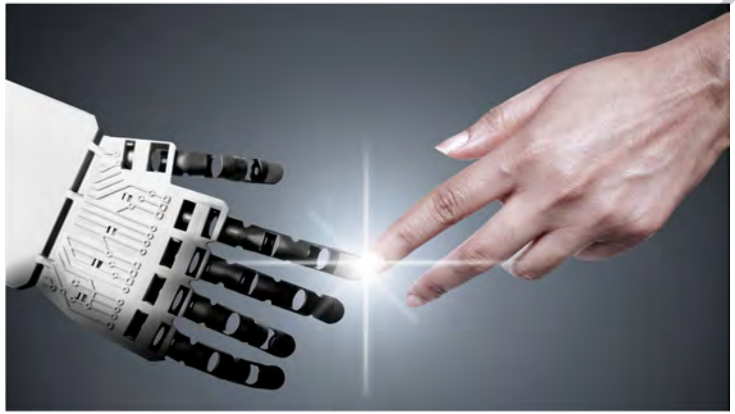
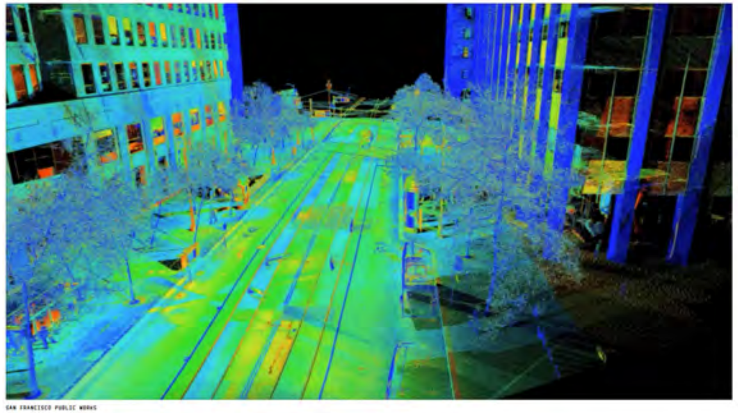


Knowing When You Don't Know: Significance and Usage





- Autonomy:
  - Safe, reliable operation by stopping
  - Human-robot collaboration through hand off
- Representations
  - Trigger to update existing representations (e.g. remapping)
  - Trigger to learn or develop entirely new types of representations (paradigm shift)

https://www.wired.com/2015/11/bombarding-san-francisco-with-lasers-to-create-a-perfect-3-d-map/

Knowing when it doesn't know is vital for both:

- **Active risk mitigation**
- **Collaboration with surgeons**

Morgan Windsor

PAPER HIGHLIGHTS

Morgan Windsor, Alejandro Fontan, Peter Pivonka, Michael J Milford, "Forward Prediction of Target Localization Failure Through Pose Estimation Artifact Modelling", *IEEE Robotics and Automation Letters*, 2024.

Morgan Windsor, Jing Peng, Ashish Gupta, Peter Pivonka, Michael J Milford, "Pose Quality Prediction for Vision Guided Robotic Shoulder Arthroplasty", in *IEEE International Conference on Robotics and Automation*, 2023

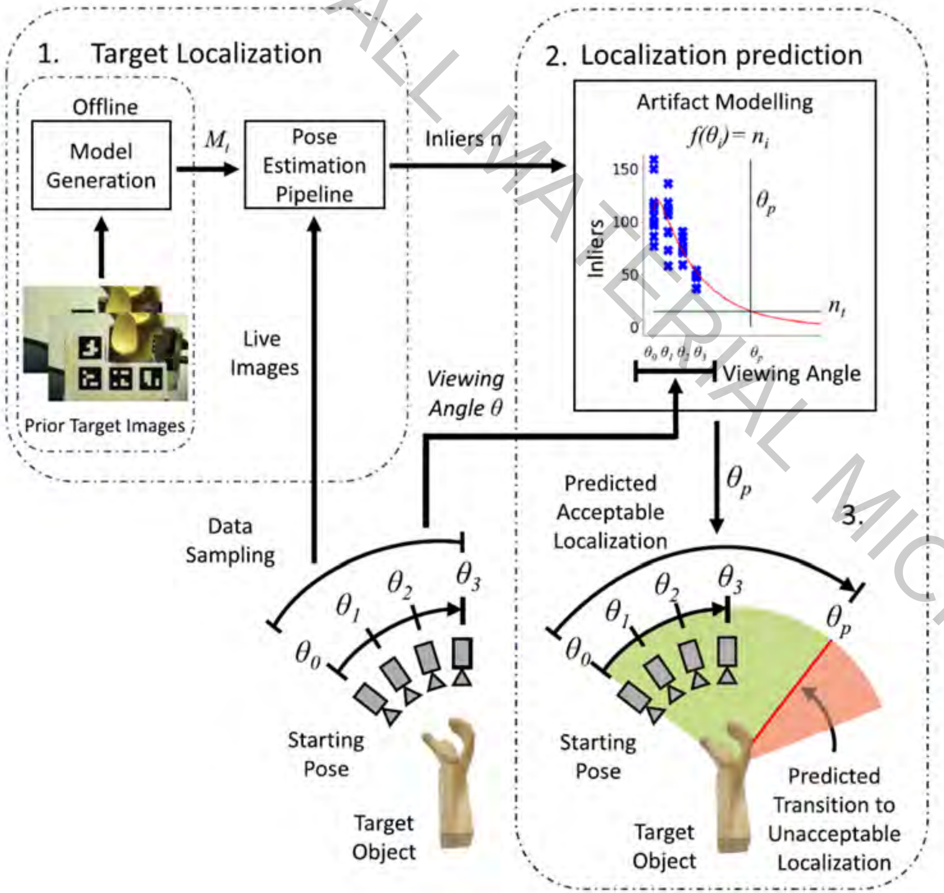
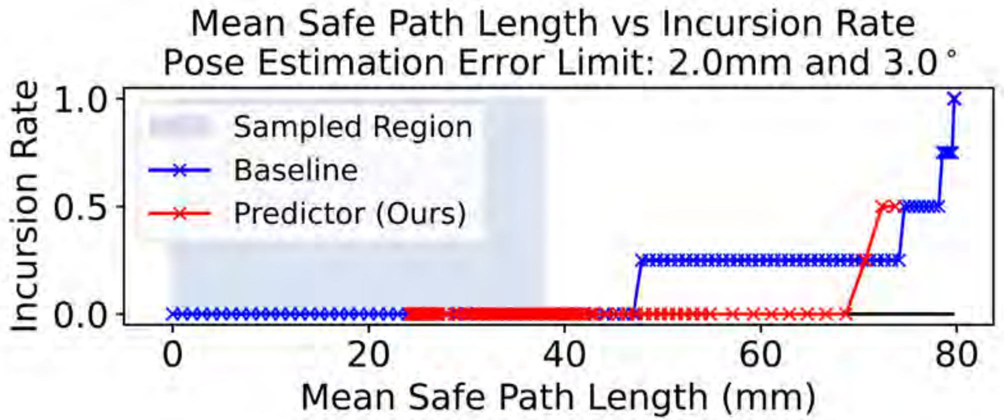
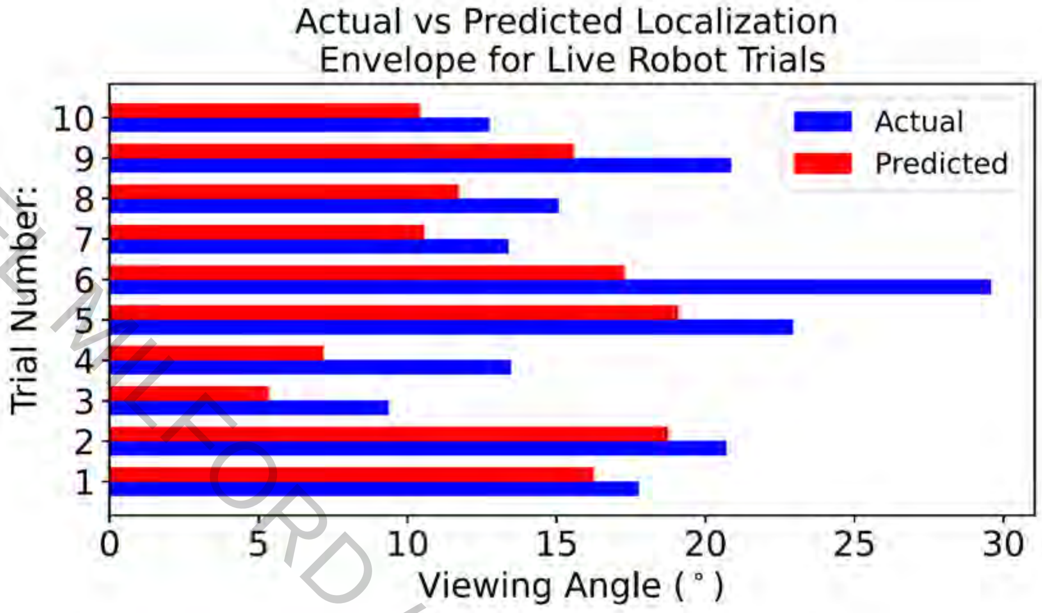


Fig. 1. Our approach extracts artifacts from a pose estimation pipeline (1) and builds a model of the artifact with respect to robot pose (2). This model is then used to predict where localization performance is likely to transition between acceptable and unacceptable performance (3).





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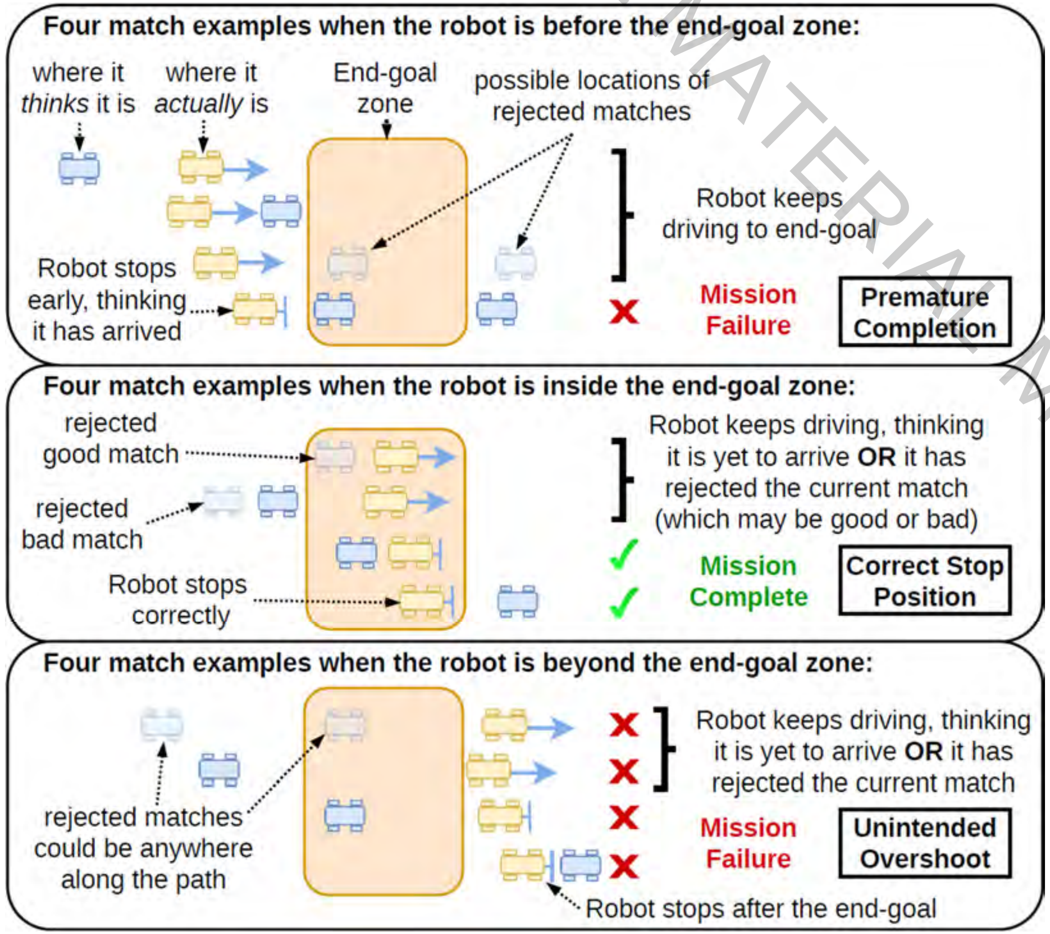
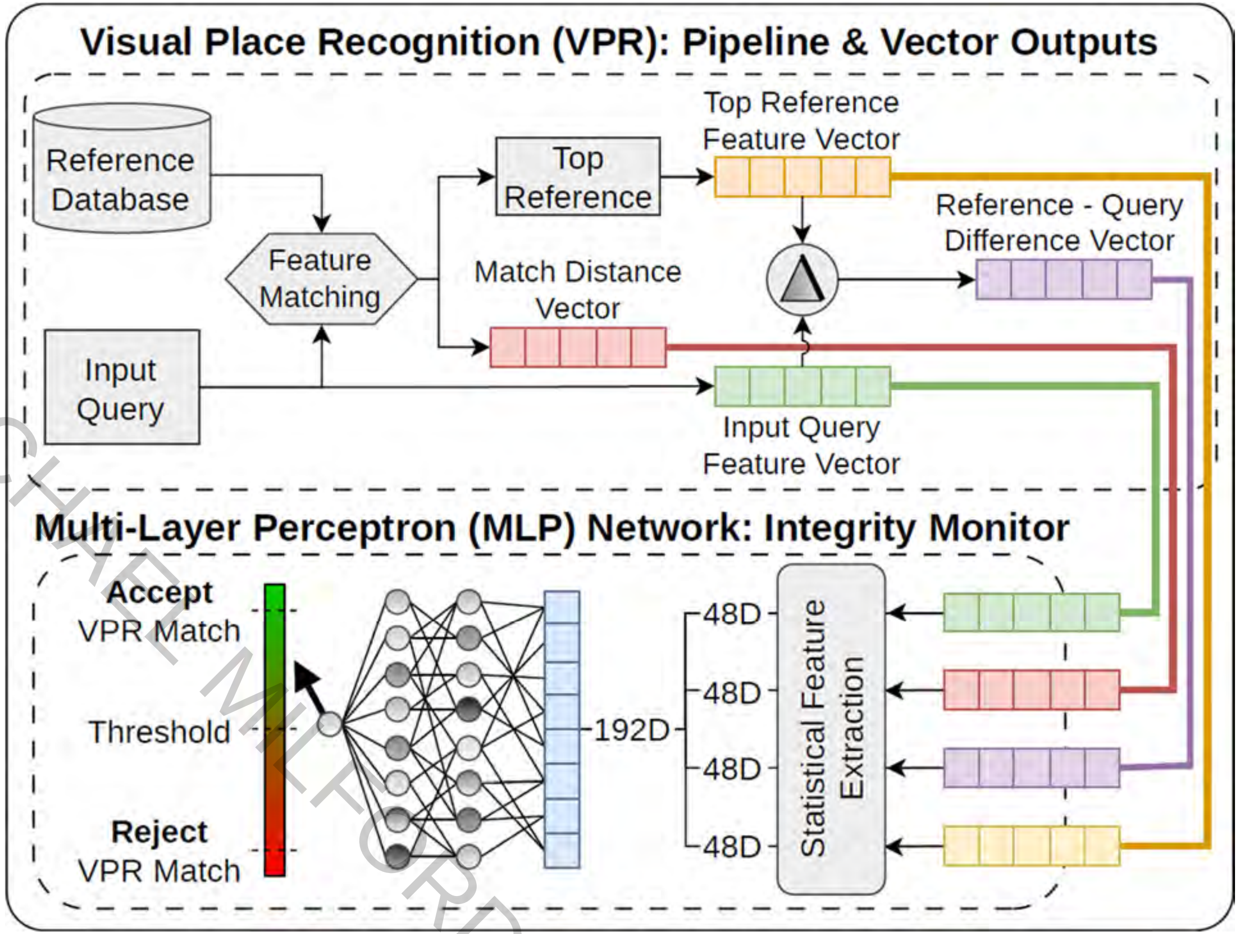
Morgan Windsor, Jing Peng, Ashish Gupta, Peter Pivonka, Michael J Milford, “Pose Quality Prediction for Vision Guided Robotic Shoulder Arthroplasty”, in *IEEE International Conference on Robotics and Automation*, 2023

Dealing with Adversity and Adversarial Interference

PAPER HIGHLIGHTS

Owen Claxton, Connor Malone, Helen Carson, Jason J. Ford, Gabe Bolton, Iman Shames, Michael Milford1 Senior Member, IEEE, "Improving Visual Place Recognition Based Robot Navigation By Verifying Localization Estimates", in *IEEE Robotics and Automation Letters*, 2024.





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A Technology That Isn't Accepted and Embraced by End-Users and Stakeholders is Worse Than Useless

PAPER HIGHLIGHTS

Burdon, Mark, Cohen, Tegan, Buckley, Josh, & Milford, Michael (2024) From object obfuscation to contextually-dependent identification: enhancing automated privacy protection in street-level image platforms (SLIPs). *Information and Communications Technology Law*, 33(2), pp. 198-221.

Privacy and Societal Acceptance

ABC NEWS Just In For You Politics World Business More Log in

We hacked a robot vacuum — and could watch live through its camera

https://www.abc.net.au/news/2024-10-04/robot-vacuum-hacked-photos-camera-audio/104414020

Streisand Effect

https://en.wikipedia.org/wiki/Streisand_effect

History and etymology [edit]

In 2003, American singer and actress Barbra Streisand sued photographer Kenneth Adelman and Pictopia.com for US$50 million for violation of privacy.[7][8][9] The lawsuit sought to remove "Image 3850", an aerial photograph in which Streisand's mansion was visible, from the publicly available California Coastal Records Project of 12,000 California coastline photographs, documenting coastal erosion and intended to influence government policymakers, of which the photograph of her residence was an overlooked and inconsequential tidbit of information.[4][10][11][12][13] The lawsuit was dismissed and Streisand was ordered to pay Adelman's $177,000 legal attorney fees.[7][14][15][16][17]

"Image 3850" had been downloaded only six times prior to Streisand's lawsuit, two of those being by Streisand's attorneys.[18] Public awareness of the case led to more than 420,000 people visiting the site over the following month.[19]

Privacy and Societal Acceptance

https://www.sfgate.com/local/article/Google-Street-View-blurred-houses-14096605.php

INFORMATION & COMMUNICATIONS TECHNOLOGY LAW
2024, VOL. 33, NO. 2, 198–221
https://doi.org/10.1080/13600834.2024.2321052

Routledge
Taylor & Francis Group

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From object obfuscation to contextually-dependent identification: enhancing automated privacy protection in street-level image platforms (SLIPs)

Mark Burdon[a], Tegan Cohen[b], Josh Buckley[c] and Michael Milford[d]

[a]Digital Media Research Centre/School of Law, Queensland University of Technology (QUT), Brisbane, Australia; [b]ARC Centre of Excellence for Automated Decision-Making and Society (ADM+S)/School of Law, QUT, Brisbane, Australia; [c]School of Law/Centre of Robotics, QUT, Brisbane, Australia; [d]Centre of Robotics, QUT, Brisbane, Australia

ABSTRACT
Street-level image platforms (SLIPs) employ indiscriminate forms of data collection that include potentially privacy invasive images. Both the scale and the indiscriminate nature of data collection means that significant privacy management requirements are needed. Legal risk management is currently operated through obfuscation techniques involving certain image objects. Current SLIP object obfuscation solutions are an indiscriminate and a blunt solution to a similarly indiscriminate data collection concern. A new contextual approach to obfuscation is required that goes beyond object obfuscation. Contextually-dependent identification would seek to identify the contexts, including captured objects, which can give rise to privacy concerns. It is technically more challenging for automated solutions as it requires an assessment of the contextual situation to understand privacy risk. Context-sensitive privacy detection, combined with context-sensitive privacy-by-design processes, potentially offer a risk management solution that better situates and addresses the concerns arising from SLIP data collections.

KEYWORDS
Obfuscation; privacy torts; data protection; context; machine learning; Google Street View

I. Introduction

Obfuscation, in its humble, provisional, better-than-nothing, socially contingent way, is deeply entangled with the context of use.[1]

CONTACT Mark Burdon m.burdon@qut.edu.au

[1]Finn Brunton and Helen Nissenbaum, *Obfuscation: A User's Guide for Privacy and Protest* (The MIT Press, 2015), 95. As noted below, while we draw on Bruton and Nissenbaum's concept of obfuscation, we nevertheless use it in a different context. We consider obfuscation as a method for organisations to build privacy into data collection systems by design rather than as a form of deliberate resistance to surveillance and data collection, as described by Brunton and Nissenbaum. The use is justified because Bruton and Nissenbaum's and our considerations have a power related context that is different in application to SLIPs.

PAPER HIGHLIGHTS

Burdon, Mark, Cohen, Tegan, Buckley, Josh, & Milford, Michael (2024) From object obfuscation to contextually-dependent identification: enhancing automated privacy protection in street-level image platforms (SLIPs). *Information and Communications Technology Law*, 33(2), pp. 198-221.

Privacy and Societal Acceptance

Adam K. Taras, Niko Sünderhauf, Peter Corke, Donald G. Dansereau, Inherently privacy-preserving vision for trustworthy autonomous systems: Needs and solutions, *Journal of Responsible Technology*, Volume 17, 2024,

PAPER HIGHLIGHTS

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Things to watch out for at IROS2024 this week

Presentations & Panels

Monday

🔷 "Rethinking Spatial Representations for Robotics: Errors, Performance Metrics, and Actual Utility" - my talk at the Standing the Test of Time Workshop alongside Luca Carlone & Steven Lake Waslander

🔷 "Trusted and introspective positioning systems for people and their machines" - my talk at the Long-Term Perception for Autonomy in Dynamic Human-shared Environments: What Do Robots Need? workshop

🔷 Panel discussion at the Brain over Brawn (BoB) Workshop on Label Efficient Learning Paradigms for Autonomy at Scale

🔷 Panel discussion at the Test of Time workshop with Javier Civera, Miloš Prágr, Steven Lake Waslander and Teresa Vidal Calleja.

Tuesday

🔷 "How to Write Papers People Love Reading" - my talk at the IEEE Young Professionals at IROS 2024 workshop, alongside Cyrill Stachniss

Research Paper Talks (IROS2024, IEEE RA-L)

Wednesday

📄 Connor Malone presents "Dynamically Modulating Visual Place Recognition Sequence Length For Minimum Acceptable Performance Scenarios" w. co-authors Ankit Vora, Thierry Peynot & Michael Milford.

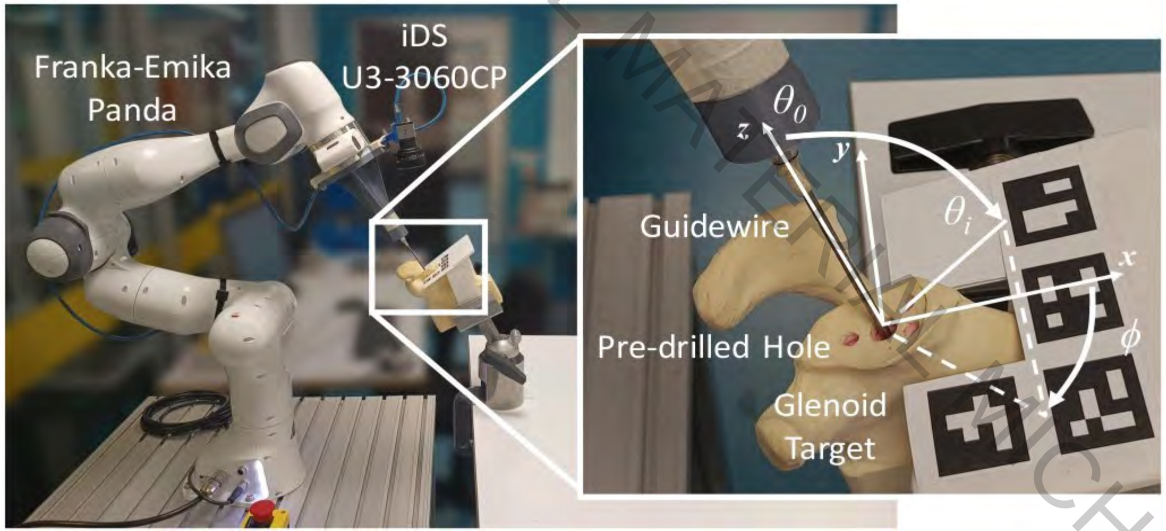
📄 Gokul B. Nair presents "Enhancing Visual Place Recognition via Fast and Slow Adaptive Biasing in Event Cameras" w. co-authors Michael Milford & Tobias Fischer.

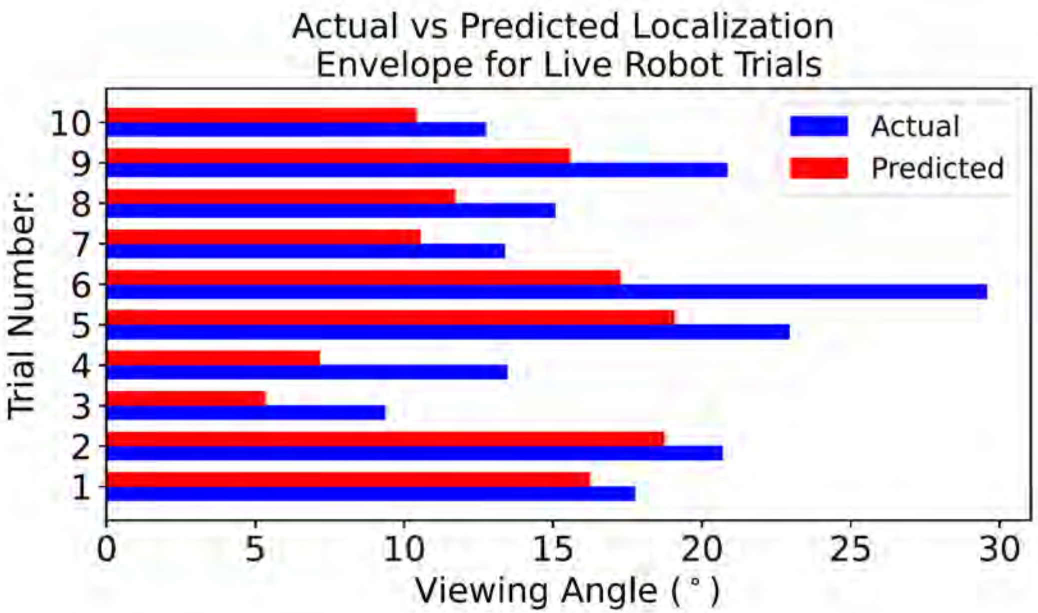
📄 On behalf of Morgan Windsor, I present "Forward Prediction of Target Localization Failure Through Pose Estimation Artifact Modelling" w. co-authors Alejandro Fontan Villacampa, Peter Pivonka & Michael Milford

Collaborators have also led the following work which will be presented:

📄 Design Space Exploration of Low-Bit Quantized Neural Networks for Visual Place Recognition, Oliver Grainge, Michael Milford, Indu Prasad Bodala, Sarvapali (Gopal) Ramchurn & Shoaib Ehsan

📄 Aggregating Multiple Bio-Inspired Image Region Classifiers For Effective And Lightweight Visual Place Recognition, Bruno Arcanjo, Bruno Ferrarini, Maria Fasli, Michael Milford, Klaus McDonald-Maier & Shoaib Ehsan

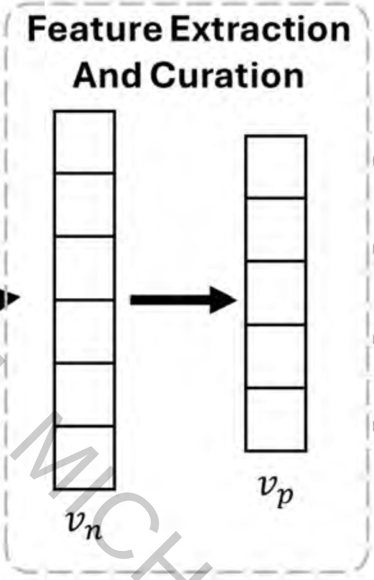




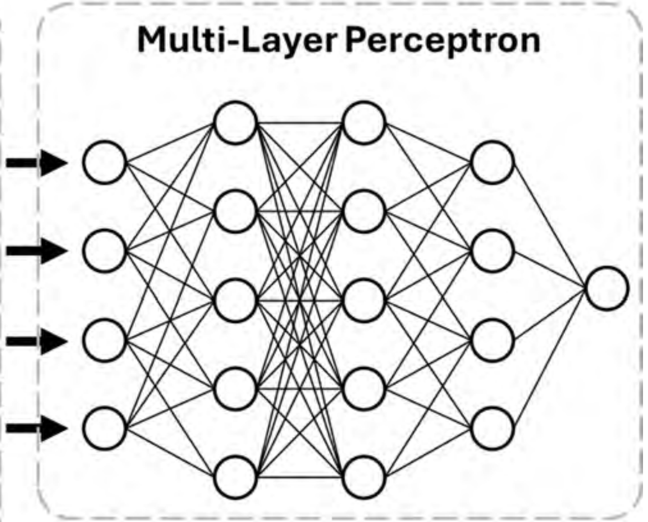
Morgan Windsor, Alejandro Fontan, Peter Pivonka, Michael J Milford, "Forward Prediction of Target Localization Failure Through Pose Estimation Artifact Modelling", *IEEE Robotics and Automation Letters*, 2024.

- Receive coarse position prior

- Retrieve reference places within

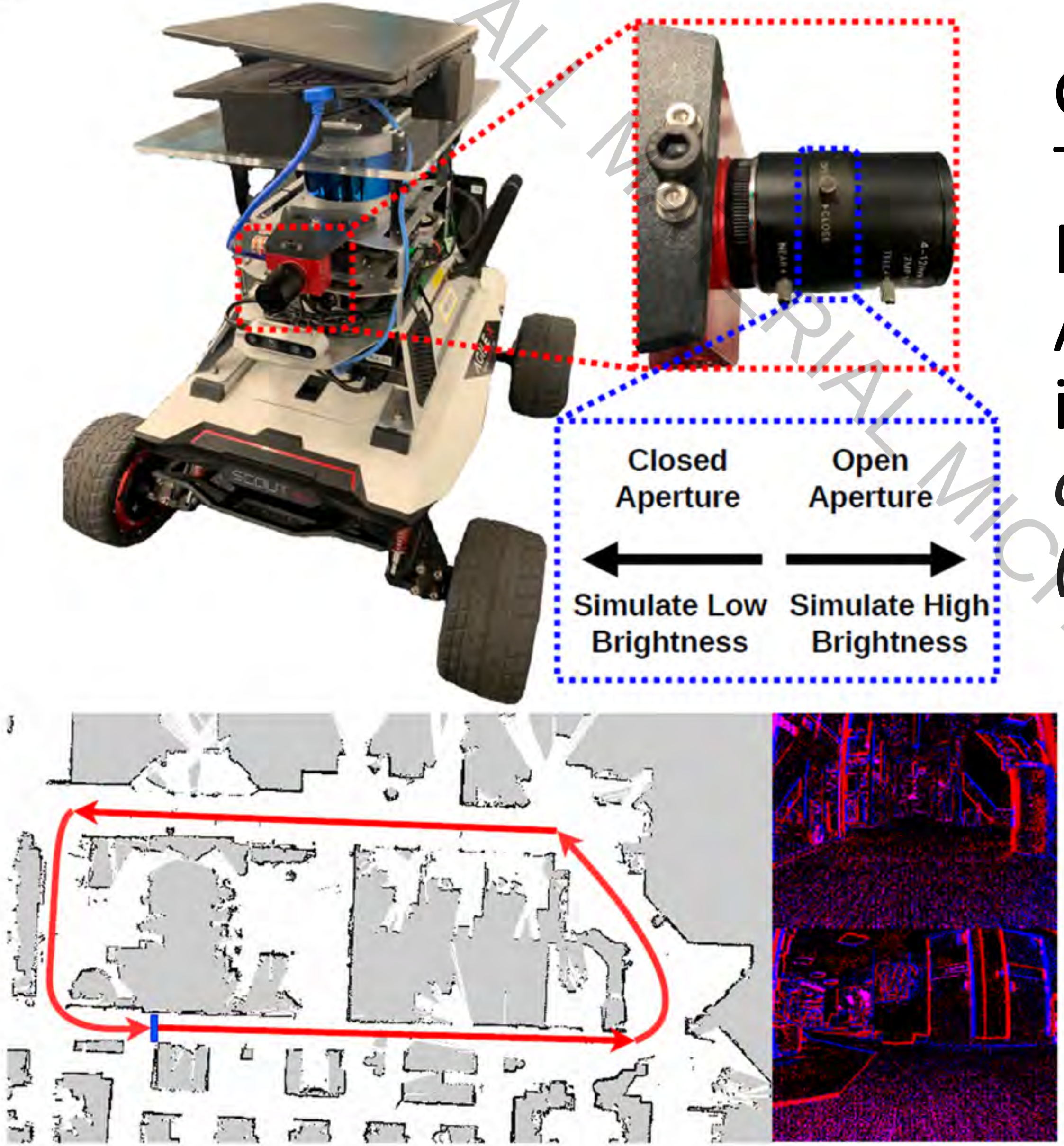


- Extract feature vector capturing appearance variation across prior



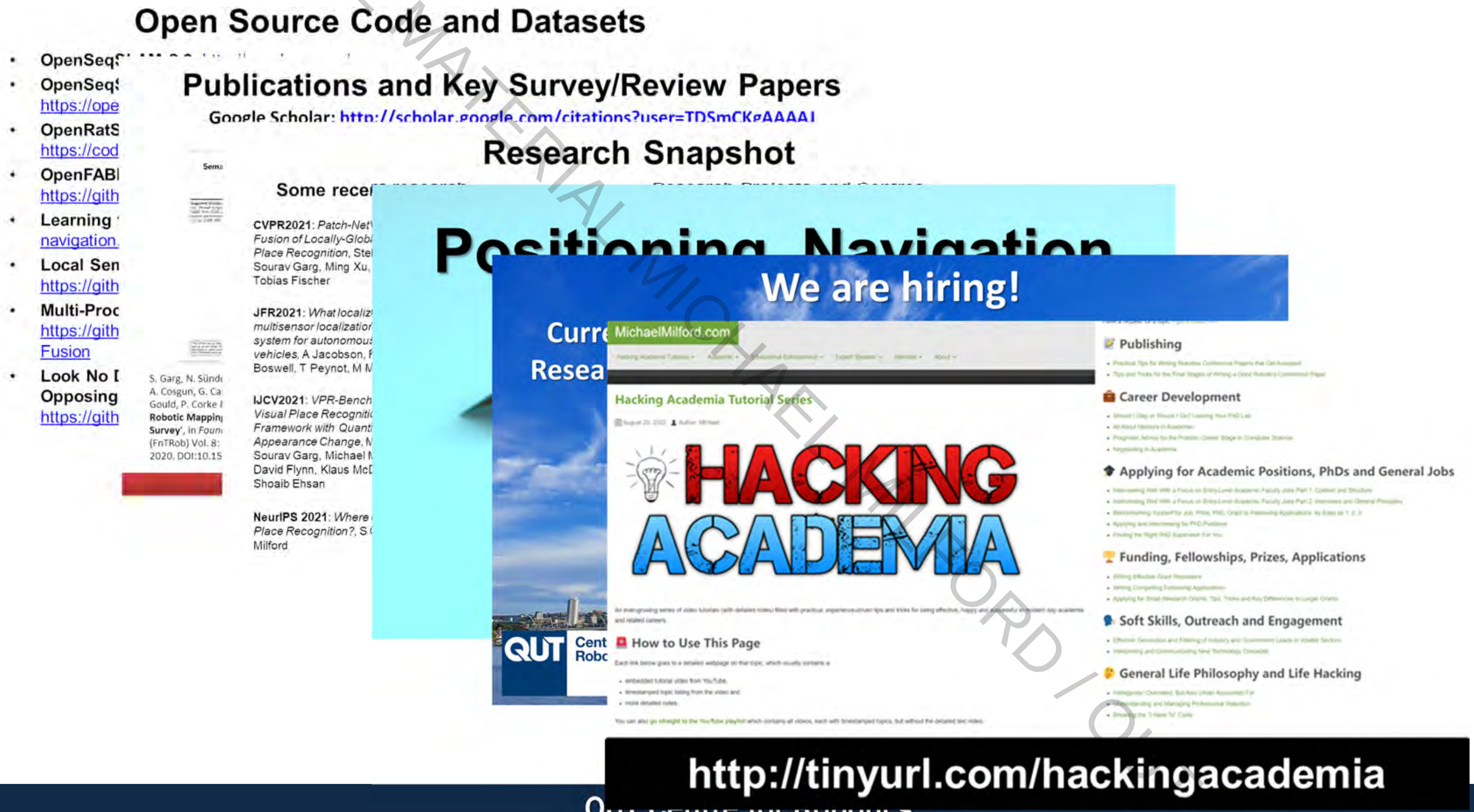
- MLP dynamically selects sequence length based on appearance variation vector

Connor Malone, Ankit Vora, Thierry Peynot and Michael Milford, "Dynamically Modulating Visual Place Recognition Sequence Length For Minimum Acceptable Performance Scenarios", in *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2024



Gokul B. Nair, Michael Milford, Tobias Fischer, “Enhancing Visual Place Recognition via Fast and Slow Adaptive Biasing in Event Cameras”, in *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2024

More Resources and Links



Collaboration Opportunities and Roles with the QUT Centre for Robotics

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Our Centre

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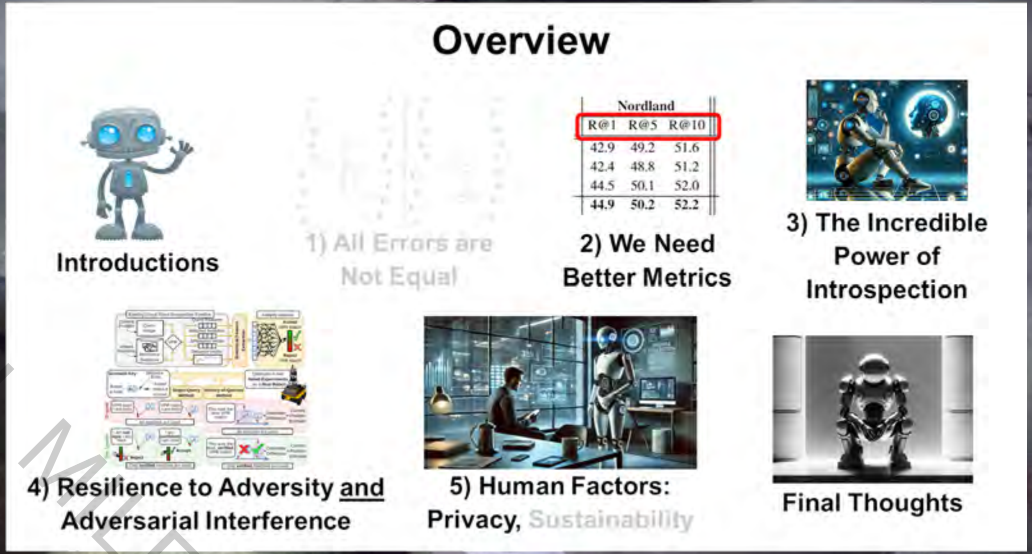

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