Robots on Sidewalks

A Brief Overview of the State of the Art for the Toronto Accessibility Committee

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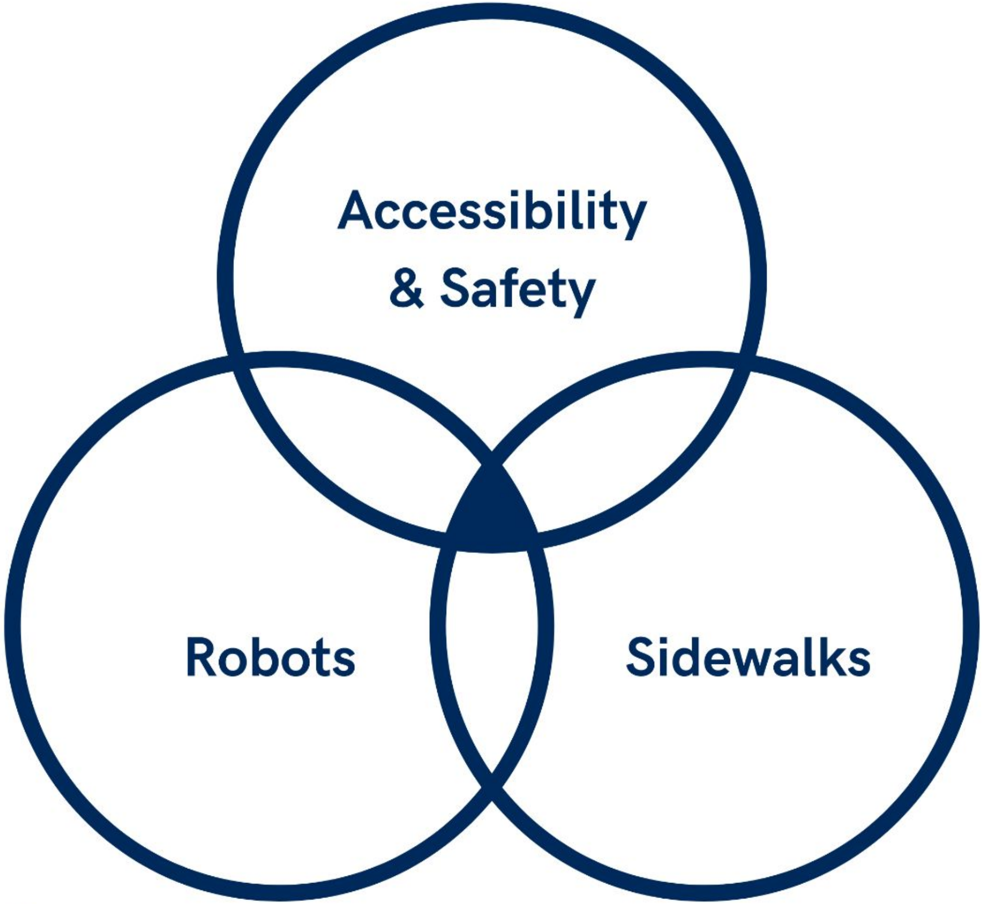
May 5, 2022



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Robots on Sidewalks

- Types and Uses
- Levels of Autonomy - what they mean and current capabilities
- The gap in accessibility-aware vision systems
- Global drivers and trends
- Toronto's opportunity

Sidewalk Robots: Types & Potential Uses

Cargo Delivery Bots

Contactless last-mile delivery of food, parcels, etc.

Photo: TinyMile

Sidewalk Patrol Bots

Remote monitoring & security

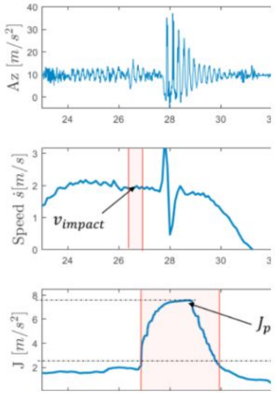
Photo: Knightscope

Snowplows & Streetcleaners

Walkway clearing & accessibility

Photo: Left Hand Robotics

Sidewalk Robots: Types & Potential Uses



Mobile Telepresence Bots

Remote mobility & interaction

Photo: Double Robotics

Sidewalk Inspection Bots

Identify/map potholes & other problem areas

Route Mapping Bots

Identify/map accessible routes & travel times

Images: Corno, 2020

The Intelligent Assistive Technology Lab at UofT is using telepresence robots to help older adults who are unable to leave their homes to stay socially connected.

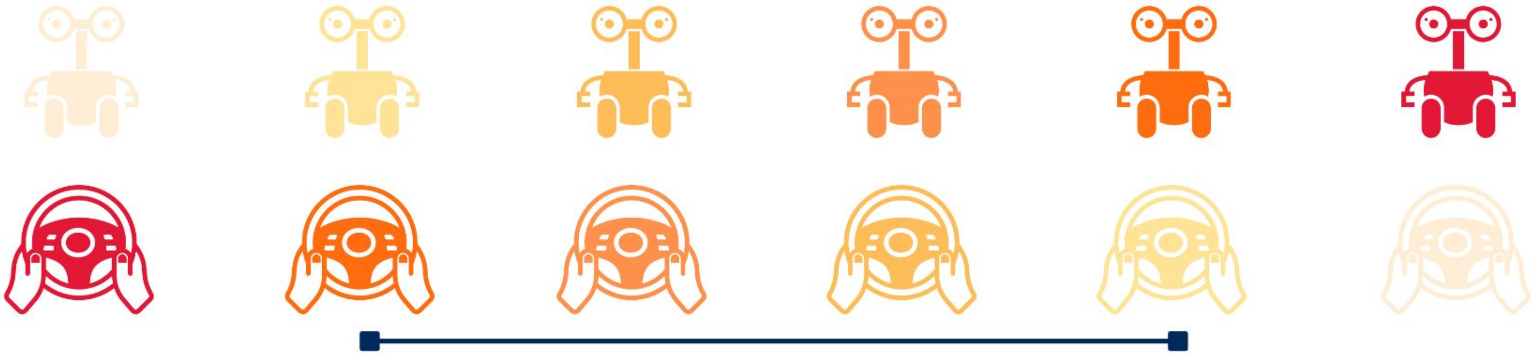
Researchers in Italy have designed a sidewalk feasibility index that considers sidewalk width, surface condition, route length and number of driveways/crosswalks present. The index can be used to quantify the accessibility of different routes for wheelchair users and people with mobility concerns. (Corno, 2020).

Sidewalk Robots: SAE Levels of Autonomy

Autonomy	None	Low	Partial	Conditional	High	Full
Level	0	1	2	3	4	5
Obstacle Sensing	No Sensing	Sense and Warn		Sense and Avoid	Sense and Navigate	

Vehicle Control

Pilot Control



Human-in-the-loop

Current real world deployments of sidewalk are remotely piloted to some degree.
The operator will step in to help with a challenging or dangerous situation.
At higher levels of autonomy, a single operator may be responsible for many robots in a large fleet.

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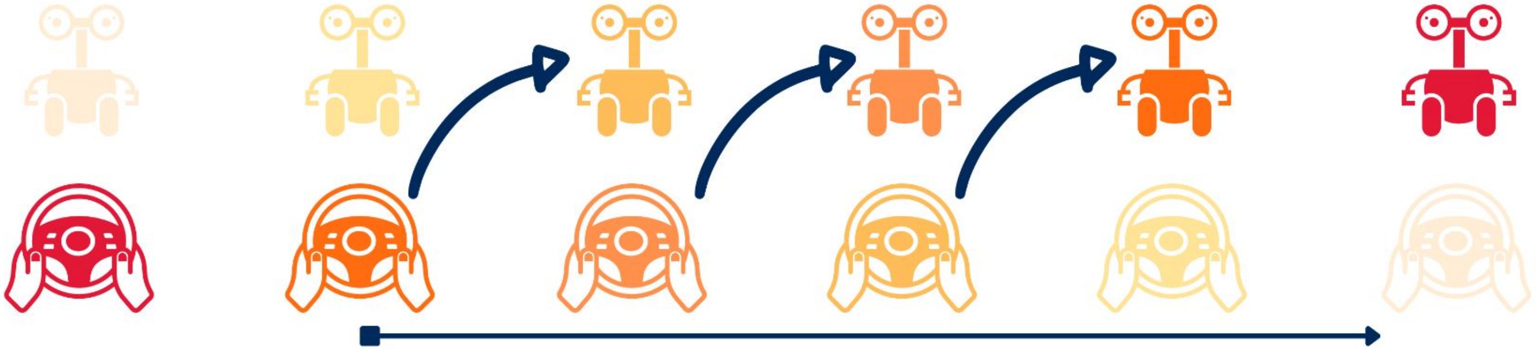

serve

STARSHIP

Learning strategies

Machine learning can enable robots to learn from the actions of their human operators and from trial and error. With sufficient training, sidewalk robots can reach higher levels of autonomy. As they become increasingly autonomous, they will rely more on visual information from their cameras and sensors to make decisions on their own.

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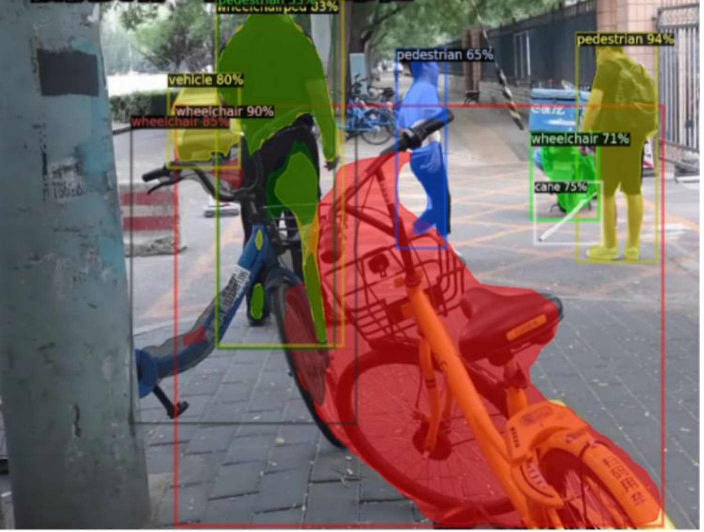

Sidewalk Robots: The Gap in Accessibility-Aware Vision Systems

Large image data sets generated by the growing body of research on self-driving cars have led to steady improvements in machine perception of people.

BUT people with disabilities are not well represented in these data sets because encounters with them are a relatively rare occurrence:

- Few annotations for mobility aids (e.g. canes and walkers)
- Lack of simulation support for predicting how the movement of people with disabilities may be different from other pedestrians

As a result, detection errors, including false positives (top image) and false negatives (bottom image) are common. (Zhang, 2021)

National Robotics Strategies Around the Globe

Multi-year flagship robotics programs from peer nations stimulate research and commercial growth, and attract talent and investment to their regions.

over **60%**

of global firms surveyed across industries anticipate near-term robot adoption

by 2025

TOP SECTORS

Mining & Metals - 90%
Oil & Gas - 79%
Manufacturing - 79%
Transportation & Storage - 69%
Energy & Utilities - 65%

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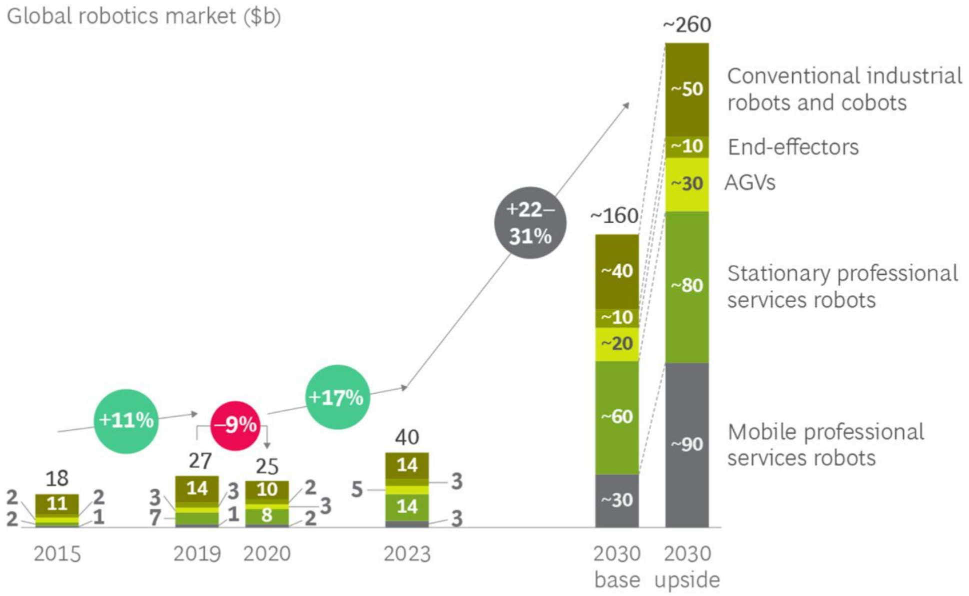
Exhibit 1 - Professional Services Robots Will Significantly Outpace Industrial Robots and Cobots in 2030



- In 2030, the global robotics total market volume is expected to reach **$160 billion to $260 billion.**
- In 2030, professional services robots (with market volume of **$90 billion to 170 billion**) will outpace conventional industrial robots and cobots (with market volume of **$40 billion to $50 billion**) by far.
- Between 2020 and 2023, the professional services robot market will grow at an annual compounded rate of **25% to 35%**.

Sources: IFR; MarketsandMarkets; BCG market model.

Note: AGVs = automated guided vehicles.

[Lassig, 2021]

Canadian Robotics Context

CIFAR

amii Mila VECTOR INSTITUTE | INSTITUT VECTEUR

$125M PAN-CANADIAN AI STRATEGY

CIFAR'S Pan-Canadian AI strategy and the Vector Institute have helped bring numerous corporate R&D centres with interest in robotics and AI to Toronto.

NVIDIA HUAWEI SAMSUNG Google LG

INNOVATION SUPERCLUSTERS

$950M SUPERCLUSTER INITIATIVE

From next generation manufacturing robots, to data-driven logistics, to precision agriculture, to autonomous ocean monitoring, each of Canada's four new Superclusters calls out robotics as either a key enabler or a beneficiary.

NGen Next Generation Manufacturing Canada

scale.ai

PROTEIN INDUSTRIES CANADA

CANADA'S OCEAN SUPERCLUSTER

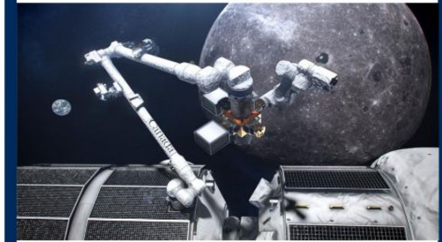
Innovation, Science and Economic Development Canada

AUTONOMOUS SYSTEMS DEEMED AN ESSENTIAL CAPABILITY

ISED's 2019 Industrial Technology Benefits (ITB) Policy lists autonomous and remotely piloted systems as an emerging Key Industrial Capability (KIC).

This means that Canada now considers these systems to be globally competitive and essential to national security.

CANADARM3



$1.9B FOR SPACE ROBOTICS

In 2019, the Canadian Space Agency (CSA) awarded MDA Robotics a contract to supply NASA with a next generation robotic arm for the International Space Station.
In 2022, MDA announced its new robotics centre of excellence would be located in Brampton.

What Canadian robotics startups have raised since 2019:

$1.1 Billion

Source: CB Insights

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Waabi, the rare autonomous vehicle startup with a woman CEO, raises $83.5 million

Raquel Urtasun helped run Uber's autonomous vehicle division in Toronto before founding her own company

By Andrew J. Hawkins | @andyjayhawk | Jun 8, 2021, 6:00am EDT

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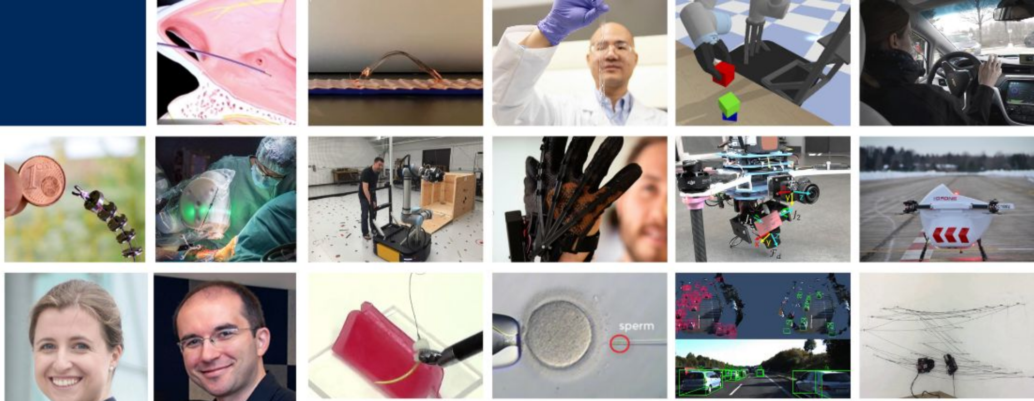
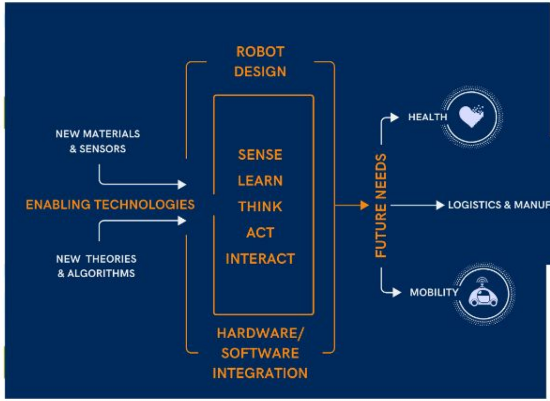
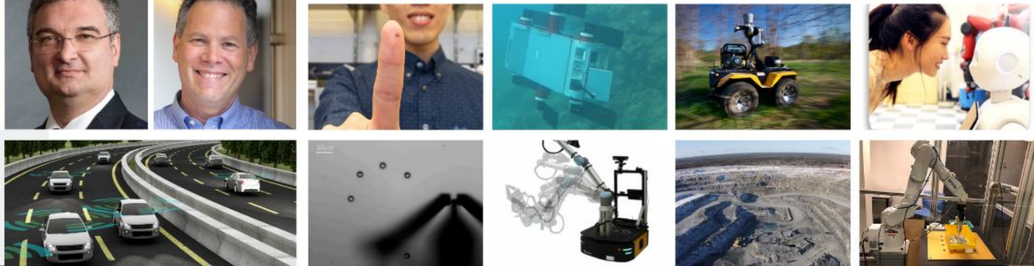


LARGEST AND MOST DIVERSE ROBOTICS RESEARCH PROGRAM IN CANADA





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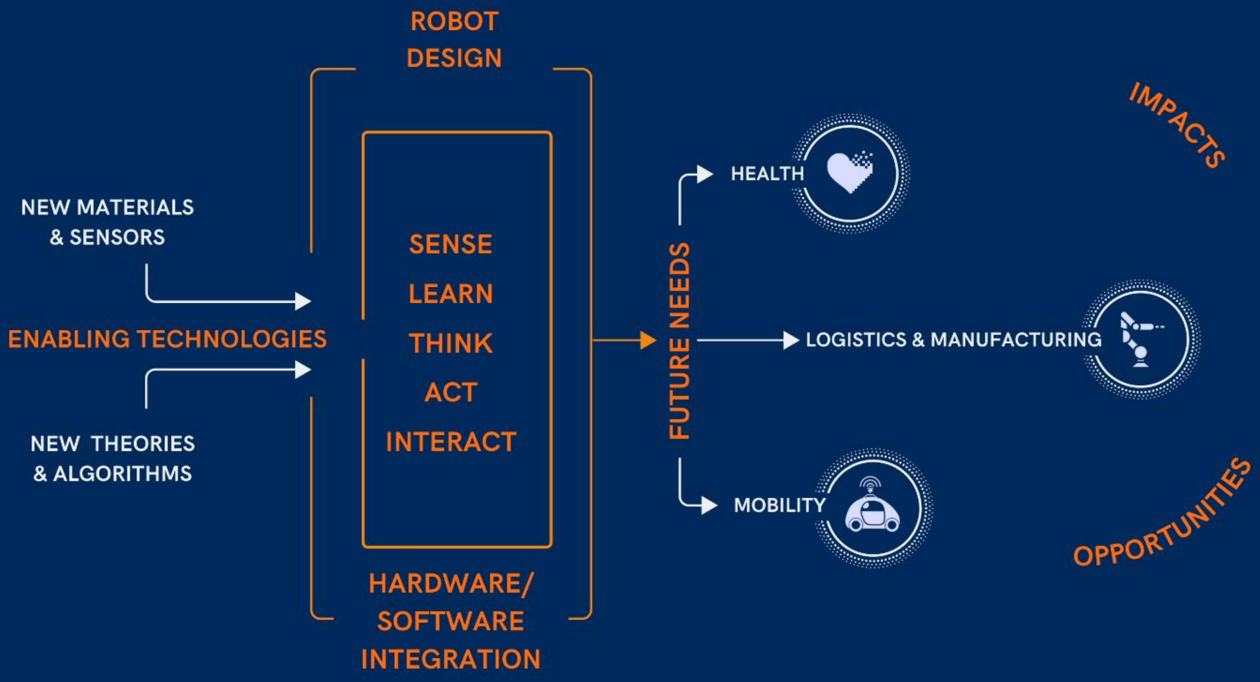
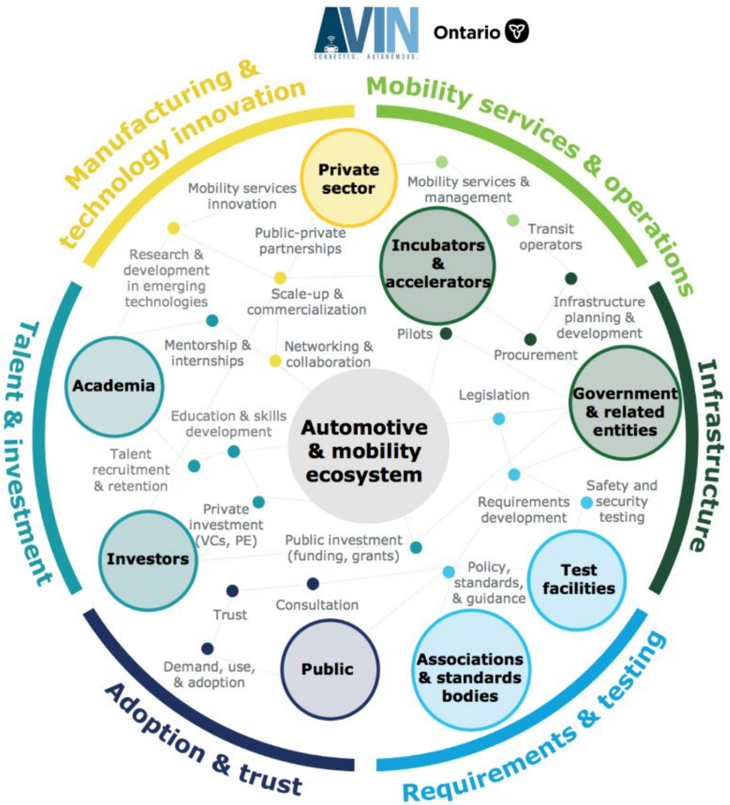
UofT Robotics Research Breadth



UofT faculty working across the frontiers of robotics innovation have a critical mass of robotics expertise that spans:

- robotics-enabling technologies (sensors, controls, machine learning and AI)
- system integration (robot perception and control)
- robot applications (healthcare, manufacturing, and mobility)
- and their impacts (cognitive, ethical, regulatory, and economic)

Sidewalk Robots: Canadian & international regulatory context



Multiple calls for building regulatory capacity, clarity, and ecosystem-level collaboration between layers of government, standards bodies, private sector, research and the public.

(Brail, 2020; AVIN, 2020; Woo, 2020)

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Sidewalk Robots: City of Toronto Opportunity

Leadership in Accessible-Aware Mobility and Vision Systems

Leadership in Inclusive, Co-Designed Mobility Solutions

Leadership in Anticipatory Autonomous Vehicles Regulation

The City of Toronto has the
opportunity for global leadership in accessible mobility innovation
IF values of inclusion and meaningful consultation with accessibility experts
is embedded into our transportation regulatory processes, infrastructure, and services.

Only by taking a pro-active approach can we ensure that inclusive values are embedded in these transformative technologies.

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Sidewalk Robots: References & Further Reading

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