Workshop R&R - Robotica, AI, Idrogeno e Rinnovabili

Energy Plants I&M via Robotics & AI

Roma 7 novembre 2024

Ferdinando Cannella

ISTITUTO ITALIANO
DI TECNOLOGIA
INDUSTRIAL ROBOTICS FACILITY

Istituto Italiano di Tecnologia - IIT

Headquarter

Genoa (Italy)

- 32.000 sqm fully equipped
- approx. 1100 scientists and staff people
- one of the largest single site lab in Europe

Other Centers

(Genoa, Italy and USA)

- 17 centers
- approx. 1500 scientists and staff people

Source: https://www.iit.it/en/

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DI TECNOLOGIA

Istituto Italiano di Tecnologia - IIT

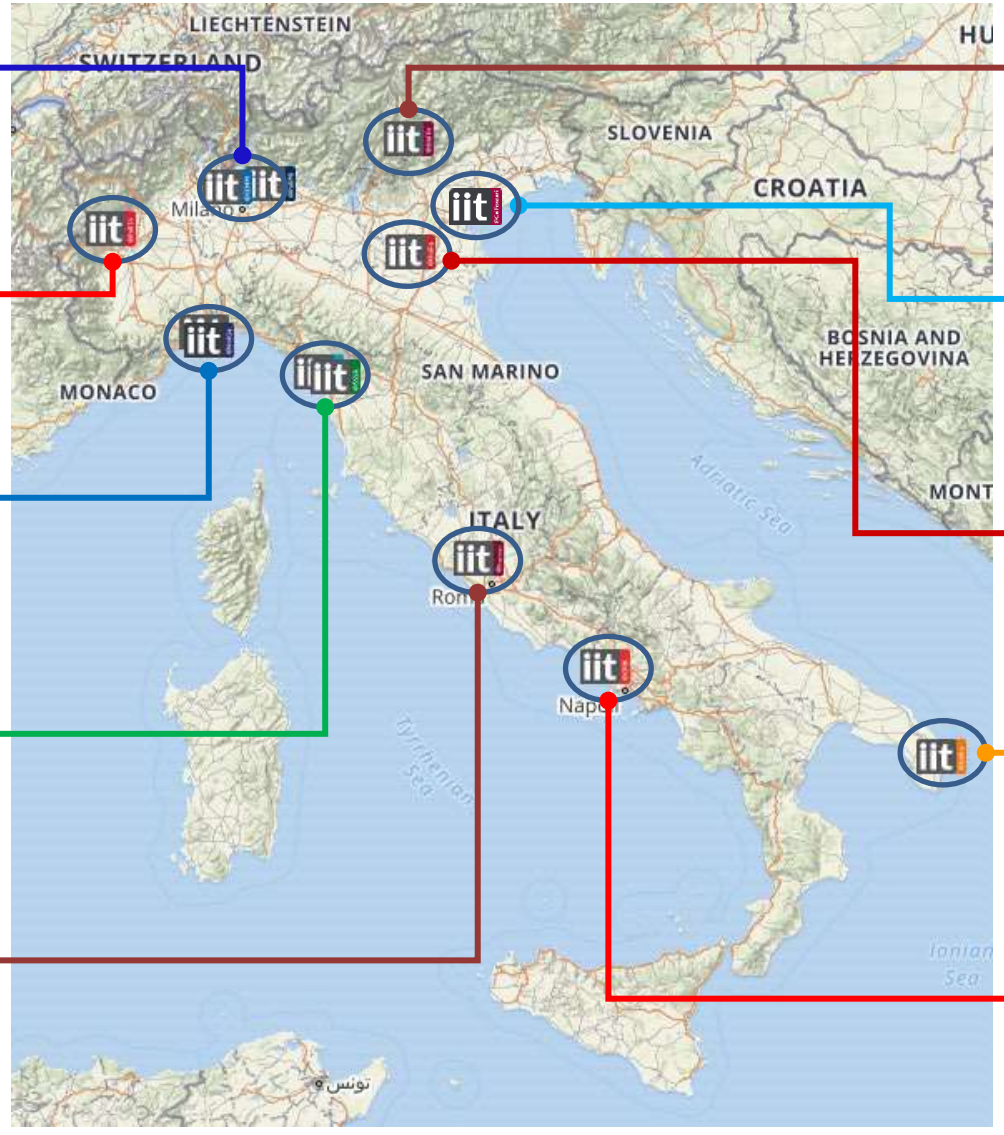
CGS@SEMM Milano
CNST@PoliMi Milano

CSFT@Polito Torino

CRIS, CHT@Erzelli, CJIR, NSYN@Unige Genova

CMBR@SSSA Pisa
CNI@NEST Pisa

CLNS@SAPIENZA Roma



CNCS@UniTn Trento

CCHT@Ca' Foscari Venezia

CTNSC@UniFe Ferrara

CBN@UniLe Lecce

CABHC@CRIB Napoli

Source: https://www.iit.it/en/web/guest/centers

ISTITUTO ITALIANO
DI TECNOLOGIA

IIT@HARVARD USA

LCSL@MIT USA

Source: https://www.iit.it/en/web/guest/centers

Istituto Italiano di Tecnologia - IIT

Research

IIT's research results aim to benefit humanity and promote prosperity by transferring knowledge and technologies to society and industry
IIT overarching priority is to develop Human-Centered Science and Technology with a multidisciplinary approach that merges different skills and expertise.

20.2k+ Publications | **66** ERC | **1335** Patents | **1817** Projects

Strategic plan

IIT's scientific activity is based on a strategic plan, updated every six years

The 2024-2029 Strategic Plan prioritizes **Artificial Intelligence for Healthcare and Earthcare**. It is organized into four research domains: Computational Science, Life Technologies (LifeTech), Nanomaterials, and Robotics. Each research domain consists of independent research units, each led by a principal investigator, and it is supported by state-of-the-art facilities.

Computational Sciences

Our focus is on massive simulations of physical systems, repeated to generate robust statistics, and mining vast datasets to identify explanatory patterns.

LifeTech

We are dedicated to developing advanced genetic, molecular, electrophysiological, computational, imaging, and perturbation tools aimed at dissecting the biological processes underlying brain function and RNA physiology.

Nanomaterials

Our research includes new sustainable/biodegradable materials, nanocomposites, 2D materials, nanofabrication technologies and nanodevices, and new colloidal chemistry approaches.

Robotics

We advance the state of the art by developing new robotic hardware and software in platforms for rehabilitation, prosthetics, surgery, agriculture, disaster recovery, industrial, and space applications.

Source: https://www.iit.it/en/web/guest/our-research

Source: https://www.youtube.com/watch?v=OnikO_T_kEk

Industrial Robotics Facility (InBot – IIT)

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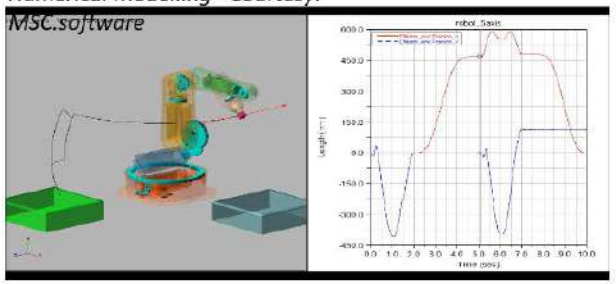
Production Process TRL9 - Courtesy: Novacart

Numerical Modelling - Courtesy:
MSC.software



Robotic Manipulation

Industrial/Civil
Robotic/Automation
Research and Applications

DECATHLON iit

SOFT MAN BOT

Demo for Decathlon Use case

Cyclists' garments

Flexible Material Manipulation and Sewing

Archeolgical Site (Pompeiii) Autonomous Monitoring System

Monitoring Robots

Maintenance Robots

Source: https://inbot.iit.it/

1ST Worldwide Autonomous Robot for Infrastructures I&M: Genova San Giorgio Bridge

FUNZIONI DEI ROBOT

MONITORAGGIO > ISPEZIONE IMPALCATO

MANUTENZIONE > PULIZIA BARRIERE ANTI VENTO E PANNELLI FOTOVOLTAICI

4 ROBOT OPERATIVI SUL PONTE
2 LATO NORD E 2 LATO SUD

PROGETTAZIONE E PRODUZIONE ESEGUITA DAL GRUPPO CAMOZZI CON LE AZIENDE INNSE BERARDI E INGERSOLL

TEST E SIMULAZIONI ROBOT CONDOTTE IN CAMOZZI ADVANCED MANUFACTURING
SU SIMULACRO PONTE (SCALA 1:1)

1ST Worldwide Autonomous Robot for Infrastructures I&M: Genova San Giorgio Bridge

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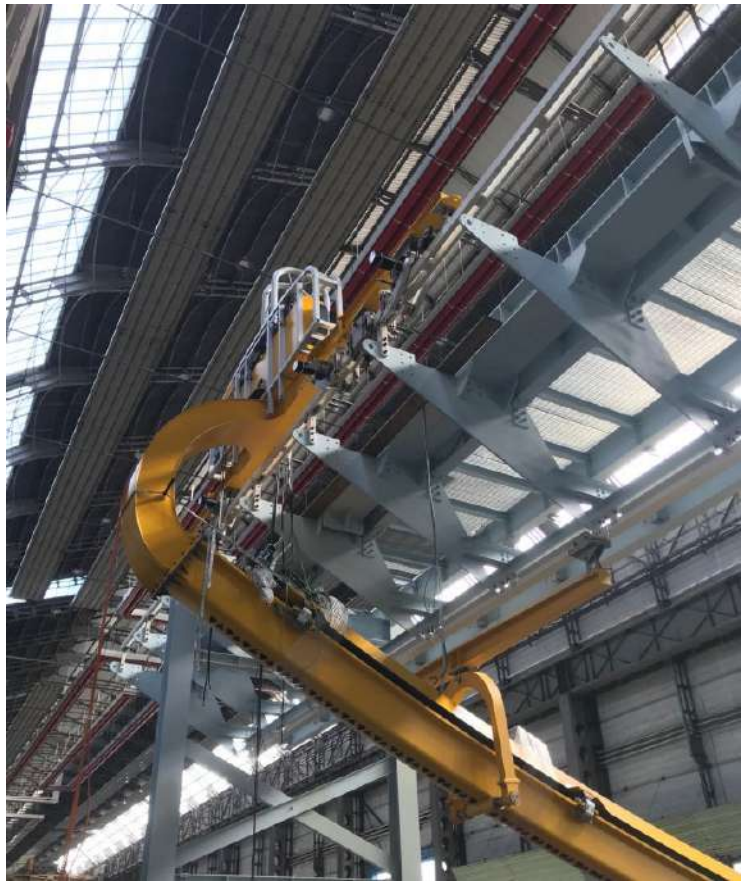

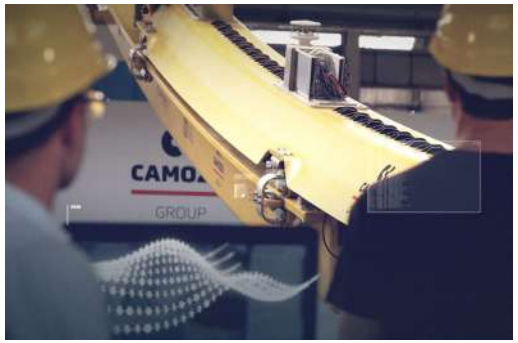

TEST CONDOTTI NELLO STABILIMENTO CAMOZZI DI MILANO
SU SIMULACRO PONTE IN SCALA 1:1

1ST Worldwide Autonomous Robot for Infrastructures I&M: Genova San Giorgio Bridge

MasterPrint®

TRAVI IN FIBRA DI CARBONIO PROGETTATE E PRODOTTE IN COLLABORAZIONE CON INGERSOLL

LUNGHEZZA 13 M
ELEVATA RIGIDEZZA
BASSO PESO (120/200 KG)
ELEVATO SMORZAMENTO
OTTIMO COMPORTAMENTO AERODINAMICO
CURA DELL'ESTETICA

1ST Worldwide Autonomous Robot for Infrastructures I&M: Genova San Giorgio Bridge

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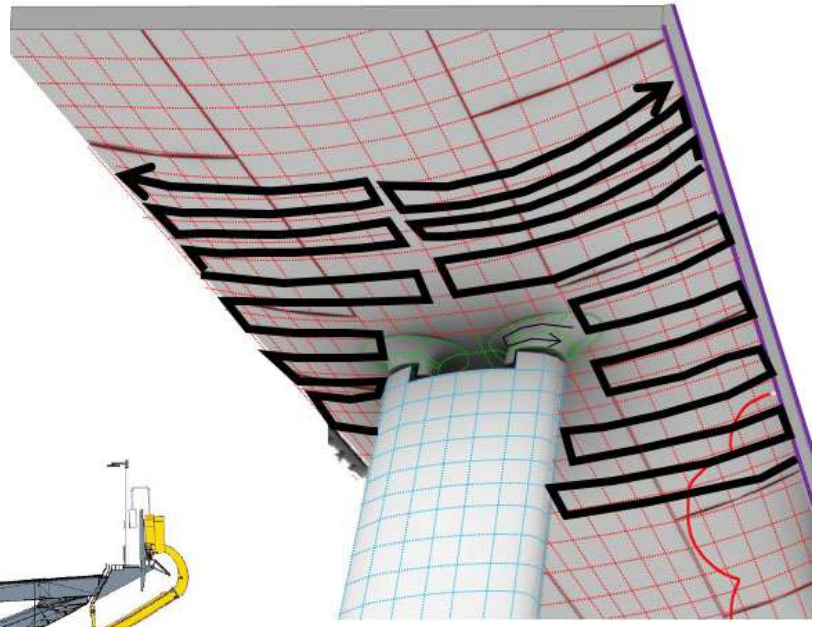
SCOPO: CREARE UN ROBOT AUTONOMO PER MONITORAGGIO (AFFIDABILITA' E RIPETIBILITA' SONO STATI I REQUISITI FONDAMENTALI)

PRINCIPALI VINCOLI DELLA PROGETTAZIONE E SOLUZIONI ADOTTATE

- DIMENSIONI: OLTRE 30 METRI DI LARGHEZZA, 6 DI SPESSORE, 1000 DI LUNGHEZZA A 45 DI ALTEZZA (SOLUZIONE: STRUTTURA AERODINAMICA, SENSORI PER MONITORARE VENTO, VIBRAZIONI E AUTONOMIA DELLE BATTERIE)
- IMPOSSIBILITA' DI AVERE DELLE GUIDE NELLA PARTE CENTRALE DELL'IMPALCATO (SOLUZIONE: STRUTTURA A MENSOLA)
- PRESENZA DELLE PILE (SOLUZIONE: BRACCIO TELESCOPICO)
- PRESENZA DI DUE ROBOT CONTEMPORANEAMENTE: UNO PER IL MONITORAGGIO E L'ALTRO PER LA PULIZIA DEI PANNELLI SOLARI E LE BARRIERE ANTIRUMORE (SOLUZIONE: MECCATRONICA COGNITIVA CHE PERMETTE DI AVERE LA PERCEZIONE DELL'AMBIENTE CIRCOSTANTE ED INTERAGIRE CON ALTRI ROBOT, PERSONE, OSTACOLI, ETC.)



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DATI PRINCIPALI	
Lunghezza ponte	1060 m
Scorrimento	Su rotaia su bordo ponte
Alimentazione	Batterie su ogni robot
Comando robot	Da control room
Trasmissione comandi	Rete Wi-fi
CN che operano in simultanea	5
ROBOT INSPECTION	
Database immagini per ogni ispezione	30.000 circa
Analisi immagini	Algoritmi di ispezione e algoritmi di change detection
Esempi di anomalie monitorate	Anomalie cromatiche Cambiamenti di profondità Cricche
ROBOT WASH	
Pulizia vetri e pannelli fotovoltaici	Tramite acqua piovana
Tempo di percorrenza ponte	3 ore circa

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SCOPO DEL WORKSHOP

Lo scopo di questo workshop è quello arrivare a **definire una tecnologia per ridurre i costi di I&M degli impianti per la produzione (e la sua distribuzione) di energia (rinnovabile e non) su cui investire nel brevissimo e medio periodo** in modo da poter gettare le basi sul lungo periodo per aumentare la competitività dell'Italia e dell'Europa nel settore energetico; tale indicazione sarà formalizzata al ministero tramite un documento condiviso e redatto da noi entro novembre.

Energy Plants I&M via Robotics & AI
INTRODUCTION

According to data from the International Energy Agency (IEA) in 2023, **the efficiency of wind and solar energy production has increased by 20% over the past five years thanks to the application of robotics and AI.** Robots and AI assist in the installation and maintenance of equipment, eliminating human errors and increasing efficiency.

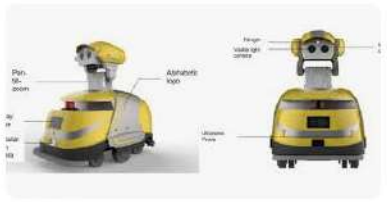
Energy Plants I&M via Robotics & AI

ROBOTICS - WHEELED


SuperDroid Robots
GPK-32 4-Wheel Drive ...

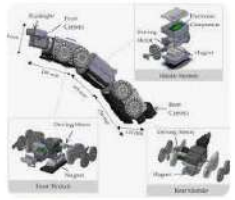

Railway-News
Wheeled Substation Inspection ...


RoboTech Vision
Autonomous robot ...

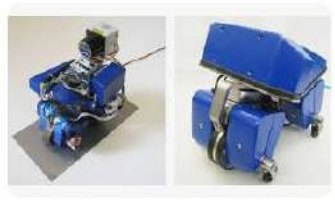

ResearchGate
intelligent inspection robot ...


YouTube
Magnetic Wheeled Robot ...


Robotnik
Robots for inspection and maintenance ...


MDPI
An In-Pipe Inspection Robot...

Fox News
The 6-wheeled robot that checks out ...


ResearchGate
magnetic wheeled inspection robot ...


DirectIndustry
Wheeled inspection r...


SuperDroid Robots
GPK-32 4-Wheel Driv...


Railway-News
Wheeled Substation Inspectio...

Robotics & Automation N...
Trustworthy Substation I...


FOXTECH Store
UGV Wheeled Pipelin...


Nexxis
Deploying Robots in Process Plants ...


Baker Hughes DAM
Mobile Inspection Robot ...


MDPI
An In-Pipe Inspection Robot with ...


ANYbotics
Choose the Right Inspection Robot f...


FOXTECH Store
UGV Wheeled Pipelin...


Railway-News
Railway Inspection Robot ...


DirectIndustry
Wheeled Inspection ro...


RoboTech Vision
Autonomous robot will inspect a power ...


Metrology News
Advanced Robotic Inspection Solution...

ResearchGate
pipe inspection robot ...


Global Electronic Services
Guide to Industrial Inspection Robots


FOXTECH Store
UGV Wheeled Pipeline...


YouTube
Magnetic Wheeled Robot ...

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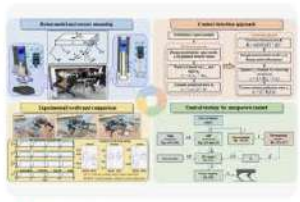
ROBOTICS - LEGGED


The Official Website Of ZhongS...
The Official Website Of Zhong...

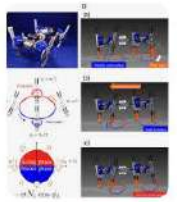

Génération Robots
quadruped robots and...


Tribotix
Go1 Quadruped Robo...

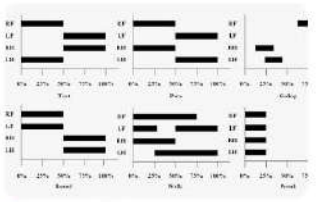

arSiv - arXiv
2107.01197] ReQuBiS...


SpringerLink
quadruped robot locomotion ...

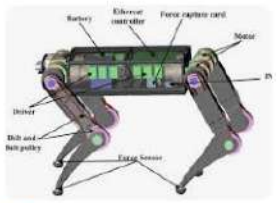
Amazon.com
HIWONDER Quadruped Robot Bionic Robot ...


ResearchGate
The quadruped rob...


CR Kennedy
Unitree Go2 Robotic ...


ScienceDirect.com
quadruped robots ...


Hackster.io
Quadruped Robot Tsuki Is ROS-Enabl...

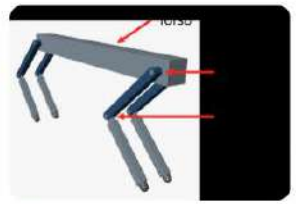

PeerJ
dynamic modeling for quadruped r...


Cryptopolitan
Revolutionary Quadruped Robo...


open-dynamic-robo...
Open Dynamic Ro...

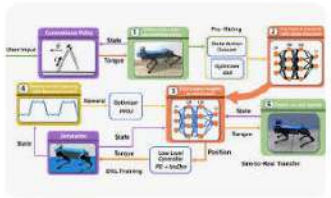

Domin
How Domin S4 Pro Servo Valves Enabl...

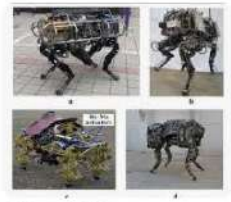

DroneBlocks
Quadruped Robotics ...


MathWorks
Quadruped Robot Locomotion Using...


InDro Robotics
newest Unitree quadrupeds ...


IEEE Spectrum
Quadruped Robots ...


Tech Xplore
Research improves quadruped bounding ...


ResearchGate
Hydraulic quadruped robots: ...


Génération Robots
Quadruped robots | G...

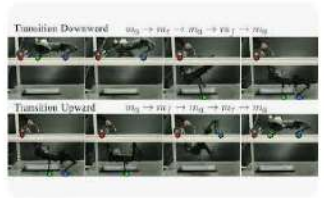

Go1 Documentation | ...
Go1 Documentation | ...


Oxford Robotics Institute - University of Oxf...
Oxford quadruped robot research teste...

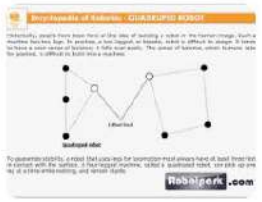

Industrial Automation Asia
DEEP Robotics Lands Applications in ...


CSIRO Research
A Versatile Multi-Limbed Inspecti...

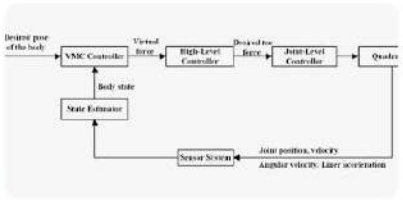
IEEE Spectrum
Quadrupedal Robot Biped ...


arXiv
Quadrupedal Robots ...


KrASIA
Deep Robotics unveils new X30 qu...


www.robotpark.com
QUADRUPED ROBOT - 21112 -...


RobotShop Community
Quadruped Robots ...



ScienceDirect.com
quadruped robots ...


YouTube
Quadruped Robots ...


InDro Robotics
InDro Robotics


MDPI
Quadruped Robot G...


CR Kennedy
Unitree B2 Robot Qua...


STEMpedia Education
Quadruped Robot: A Four-Le...

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ROBOTICS - AERIAL

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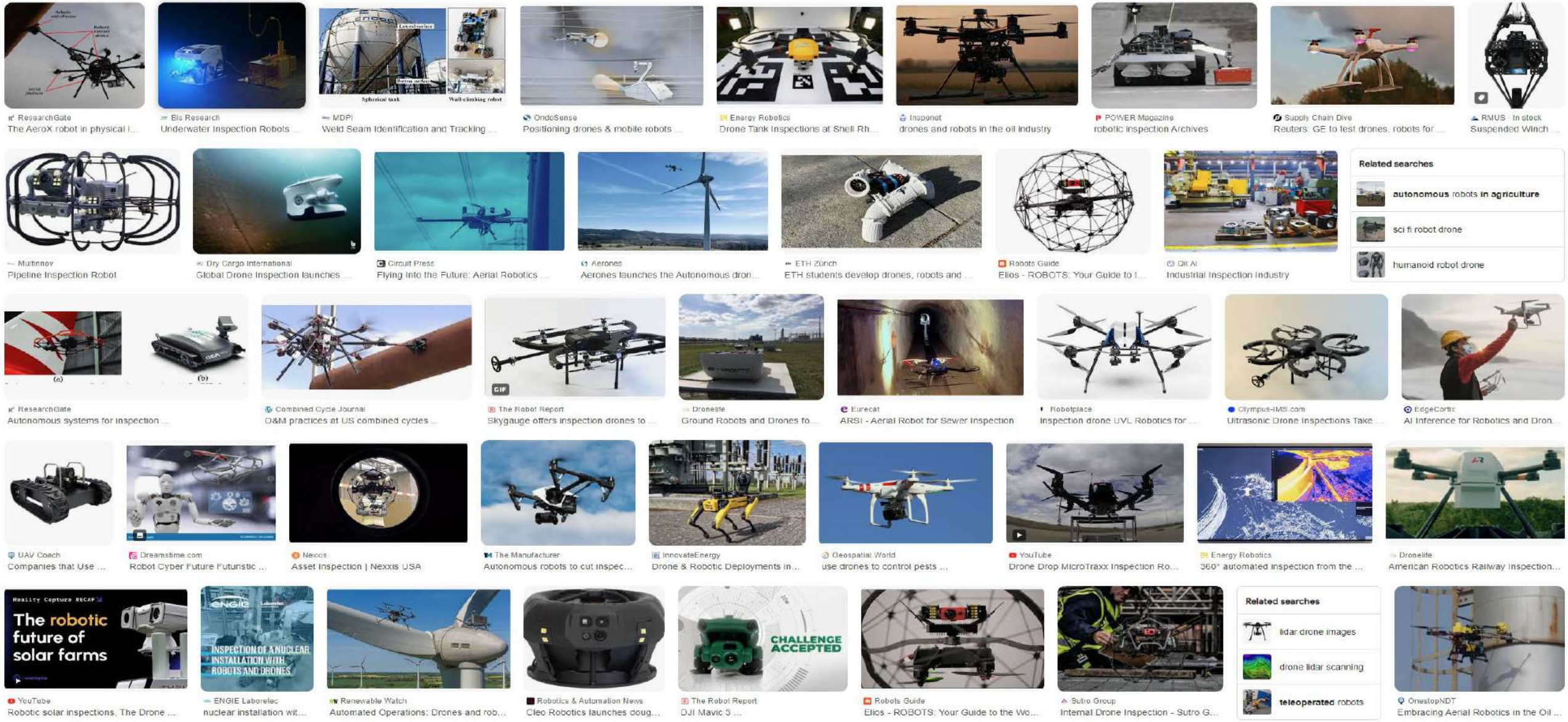

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ROBOTICS - MARINE


Thor-robotics
ROV – Thor-robotics


Amazon UK · In stock
FIFISH V6 Expert Mini Rov Submarin...


Blue Robotics
Affordable and Capable ...


Amazon UK · In stock
FIFISH V6 Expert Mini Rov Submarine ...

QYSEA
FIFISH Underwater ROV/Robot/Drone ...


Amazon.com · In stock
Mini Rov Underwater Dr...


AliExpress · In stock
200M Advanced Underw...


IndiaMART
Chasing M2 Underwater ...


UW Camera Store
Underwater inspecti...

New Atlas
Streamlined "submersible quadcopter" ...

YouTube
QYSEA: Underwater Drone Robots for ...


EyeRov
EyeRov


QYSEA
FIFISH Underwater ROV/Robot/Dro...


NauticExpo
Pipeline inspection under ...


Blue Skies Drones
Water Drones & ROVs


AliExpress · In stock
Chasing M2 Underwater Drone Rov Robot ...


Unmanned Systems Technology
Shipping Vessels ...


Amazon.com
FIFISH QYSEA V6 Expert M200A Und...


Ocean News & Technology
Underwater Inspection ...


QYSEA
FIFISH Underwater ROV/Rob...


AliExpress · In stock
Chasing M2 Underw...


Unmanned Systems Technology
ROV Robot | Deep Water ROV | R...


IndiaMART
Chasing M2 Underw...


UAVfordrone
Geneinno Underwate...


Reach Robotics
What Are Underwater ROVs & Ho...


Ocean Science & T...
ROVs for Marine &...

Blue Robotics
What is an Underwater ROV?


NS Energy
ROVs offer solutions to protect dams ...


Alibaba.com
pan tilt underwater rov ...


www.aus-rov.com.au
AUS-ROV Underwater Inspection Servi...


Amazon.com · In stock
Amazon.com : FIFISH M100A Industrial ...


Thor-robotics · In stock
ThorRobotics NEW RO...


MFE Inspection Solutions
Underwater Drone | Deep Trekker ...

Underwater Dive Services
ROV/Drones & Inspections | Underwater ...


Blue Robotics
Affordable and Capabl...


Hydro International
underwater mission specialist robot ...


Blueye Robotics
Underwater drones for port inspectio...

Facebook
Global Drone Inspection

Delair Marine
ROV inspection to coll...

Ocean Science & Technology
ROVs for Marine & Underwater P...

Wind & water works
DroneQ Robotics - Wind & water works

Amazon UK · In stock
Chasing M2 PRO ROV Underw...

JPT - Society of Petroleum Engineers
Unmanned Vehicles, Drones ...

Dry Cargo International
Global Drone Inspection launches ROV in...

Energy Plants I&M via Robotics & AI

ROBOTICS - SUMMARY

Table 1. Summary of Existing Reviews on Offshore Robotics and the Number of Robots with Manipulation Capabilities

Source	Year	Operating domain	Robot types	UAM	Climb	Leg	USV	UUV
17	2022	All	UAV, climb, leg, UUV	–	–	–	–	1
18	2019	All	UAM, leg, UUV	1	–	–	–	1
19	2018	Subsea	UAV	–	–	–	–	–
20	2022	Atmospheric, subsea	UAV, climb, UUV	–	–	–	–	5+
21	2018	Atmospheric	UAM	3	–	–	–	–
22	2022	Subsea	UUV	–	–	–	–	3
23	2019	Atmospheric	Climbing	–	2	–	–	–
24	2023	Atmospheric	Climbing	–	3	–	–	–
25	2021	Splash zone	Climbing	–	–	–	–	–
26	2023	Atmospheric	Legged	–	–	4	–	–

UAM, unmanned Aerial Manipulator; USV, unmanned surface vessel; UUV, unmanned underwater vehicle.

Source: Graafland, Jovanova, From Heights to the Deep Sea, a Review of Robots Interacting with Offshore Structures - Robotics Reports - 2024

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ROBOTICS - SUMMARY

Table 2. Summary of UAMs

Source	Year	Name	Type	#[a]	Nav.	Man.	TRL
31	2014	*AMUSE*	Octoquad	1	A[b]	A	6
32	2017	n.a.	Hexacopter	2	R[c]	R	6
34	2019	SAM	Octocopter	1	n.a.	n.a.	4
30	2014	MM-UAV	Quadcopter	2	R	R	4
35	2016	n.a.	Hexarotor	1	R	R	6
36,37	2018	*DRAGON*	Snake	2	A	A	4
38	2019	n.a.	Quadcopter	1	A	A	6
28	2020	n.a.	Hexarotor	1	A	A	7[d]
29	2019	*AeroX*	Octocopter	1	R	A	7[d]

Source: Graafland, Jovanova, From Heights to the Deep Sea, a Review of Robots Interacting with Offshore Structures - Robotics Reports - 2024

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ROBOTICS - SUMMARY

Table 3. Summary of Climbing Robots

Source	Year	Name	Locomotion	Adhesion	#[a]	Surface	Nav.	Man.	TRL
40	2014	*BladeBUG*	Legged	Suction	n.a.	Turbine blade	n.a[b]	n.a.	7
41	2016	n.a.	Wire driven	Wires	2	n.a.	A[c]	A	6
42	2020	n.a.	Wheeled	Magnetic	1	Metal	R[d]	n.a.[e]	4
43	2016	*Climbot*	Legged	Clamping	1	Poles	R	R	6[f]
44	2019	*CMBOT*	Legged	Clamping	1	Handrails	A	R	5

Source: Graafland, Jovanova, From Heights to the Deep Sea, a Review of Robots Interacting with Offshore Structures - Robotics Reports - 2024

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ROBOTICS - SUMMARY

Table 6. Summary of Underwater Robots

Source	Year	Name	Depth (m)	Shape	#[a]	Nav.	Man.	TRL
58,61	2018	*Aquanaut*	3000	Torpedo/Humanoid	2	A[b]	R[c]	9
59	2018	—	1500	Torpedo/Isotropic	—	A	—	3
60	2022	*Cuttlefish*	1000	Box	2	A	A	4
63	2011	*Sabertooth*	3000	Box	1	A	R	9
64,65	2017	*Eely500*	500	Snake	1	A	R	8
72	2018	USM	—	Snake	1	A	A	2
66,67	2023	*Cyclops × child*	100	Box	1	A	A	7
68	2021	*TWINBOT*	500	Multi-Torpedo	1	A	A	5
69,70	2011	*GIRONA 500*	500	Multi-Torpedo	1	A	A	9
71,73	2017	*Ocean One*	91[d]	Humanoid	2	A	R	8

Source: Graafland, Jovanova, From Heights to the Deep Sea, a Review of Robots Interacting with Offshore Structures - Robotics Reports - 2024

ROBOTICS - SUMMARY

Limits:

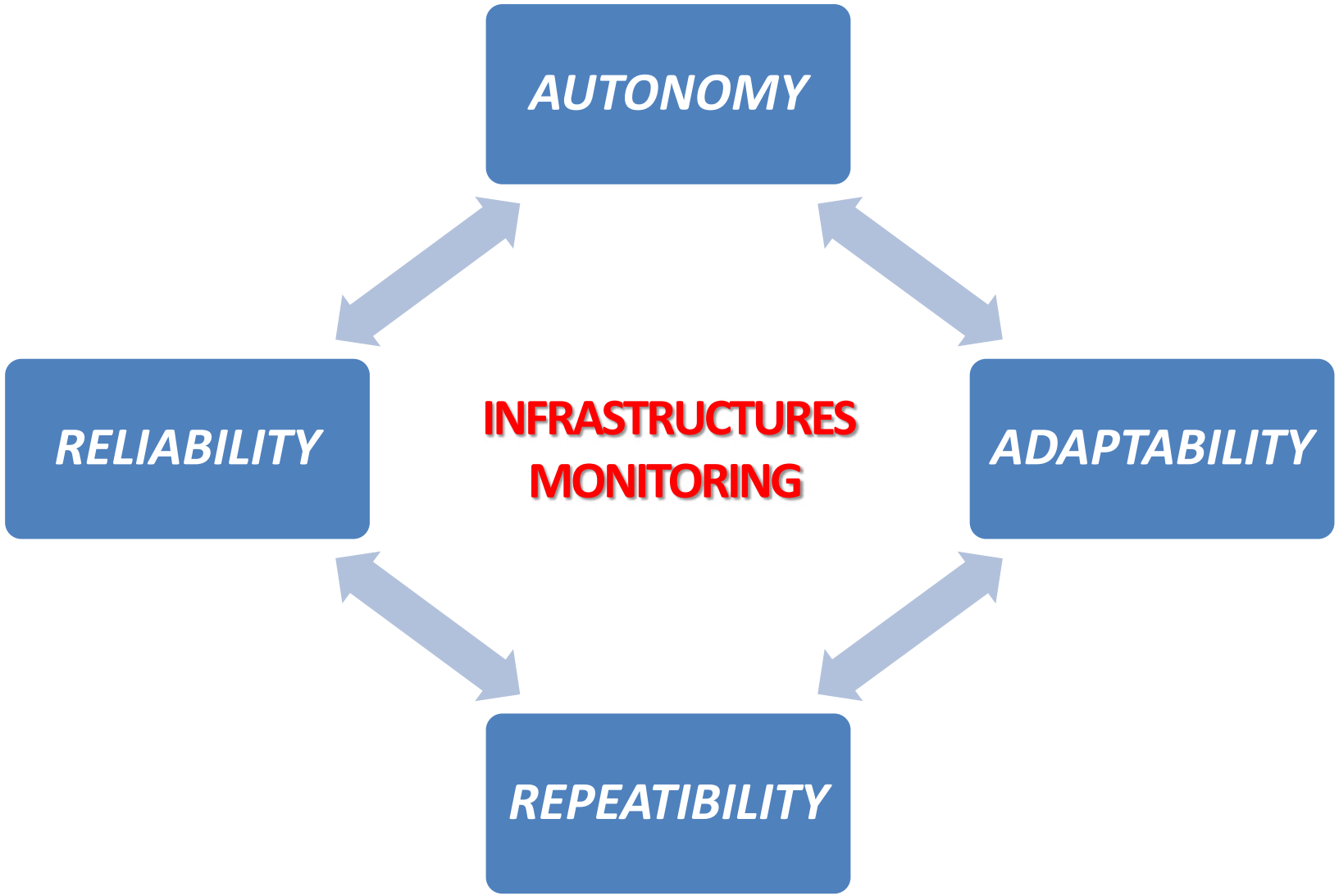
- Battery Life and Operation Time Limit: robots operational time is limited by its battery life, which typically lasts around 40 minutes for drones and 90 minutes for legged robots under normal conditions. This can be a constraint for lengthy or continuous inspections in large or complex energy plants. Impact: Frequent recharging or battery swaps are needed for extended missions, potentially disrupting continuous monitoring activities.

- Environmental Conditions Limit: these robots are designed to handle rough terrain and various environmental conditions, but extreme environments in energy plants—such as high radiation areas, extremely high or low temperatures, or areas with explosive gases—can pose challenges. Impact: In extreme conditions, the robots might not be able to operate effectively or safely, limiting its utility in certain sections of energy plants, especially nuclear or certain chemical processing facilities.

- Autonomy and Navigation Limit: Although the robots are equipped with sophisticated sensors and navigation capabilities, its autonomy is still limited in highly dynamic or cluttered environments. It can struggle with complex or unpredictable layouts, and it may require human intervention to navigate certain areas. Impact: This may limit Spot's ability to perform fully autonomous inspections, requiring human oversight or pre-programming for specific routes, which can reduce efficiency.

ROBOTICS I&M REQUIREMENTS

IN THEORY!!!! ☺



MONITORING and MAINTENANCE

ROBOTICS - Bridges

ISTITUTO ITALIANO DI TECNOLOGIA

https://www.youtube.com/watch?v=-LmAcL2WFFo

Traditional bridge inspections

- Time consuming
- Dangerous
- Expensive
- Imprecise
- Imperfect record keeping
- Lack of comparison data to previous year

(ALMOST) NO MONITORING!!!

https://www.flyability.com/articles-and-media/drones-bridge-inspection

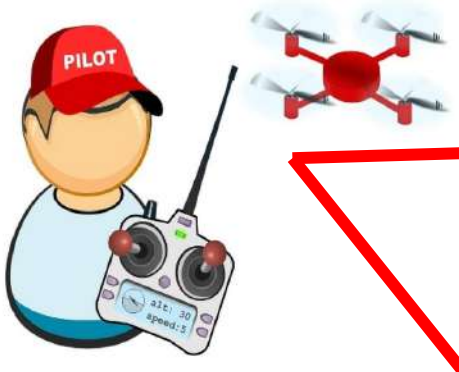
Advanced bridge inspections

- Inspection road and highway damage due to environmental impact and natural erosion.
- Maintain bridges, tunnels and other critical infrastructure to help reduce the cost of on-demand maintenance. Perform railway inspections frequently and efficiently to avoid damage and derailment.
- View seaports, canals, and waterways in superior detail and accuracy.
- Faster Inspection
- No road partial/total closure and traffic issues
- Repeatability is not guaranteed and then there will be lack of comparison with data to previous years.

MONITORING and MAINTENANCE

ROBOTICS - Bridges

NEEDS AN OPERATOR!!!



MONITORING and MAINTENANCE

ROBOTICS - Bridges

High Tech Structure!!!!

Monitoring and Maintenance Robotic System for San Giorgio Bridge (Genoa, Italy)

ROBOTICS – Photovoltaic Plants

NO AUTONOMY/ NO ADAPTABILTY!!!

Courtesy: https://solarcleano.com/en/

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DI TECNOLOGIA

ROBOTICS – Photovoltaic Plants

ROBOTICS – Photovoltaic Plants

Courtesy: https://solarcleano.com/en/

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Courtesy: https://solarcleano.com/en/

ROBOTICS – Photovoltaic Plants

AUTONOMY/ NO ADAPTABILITY!!!

Courtesy: https://www.serbot.ch/en/

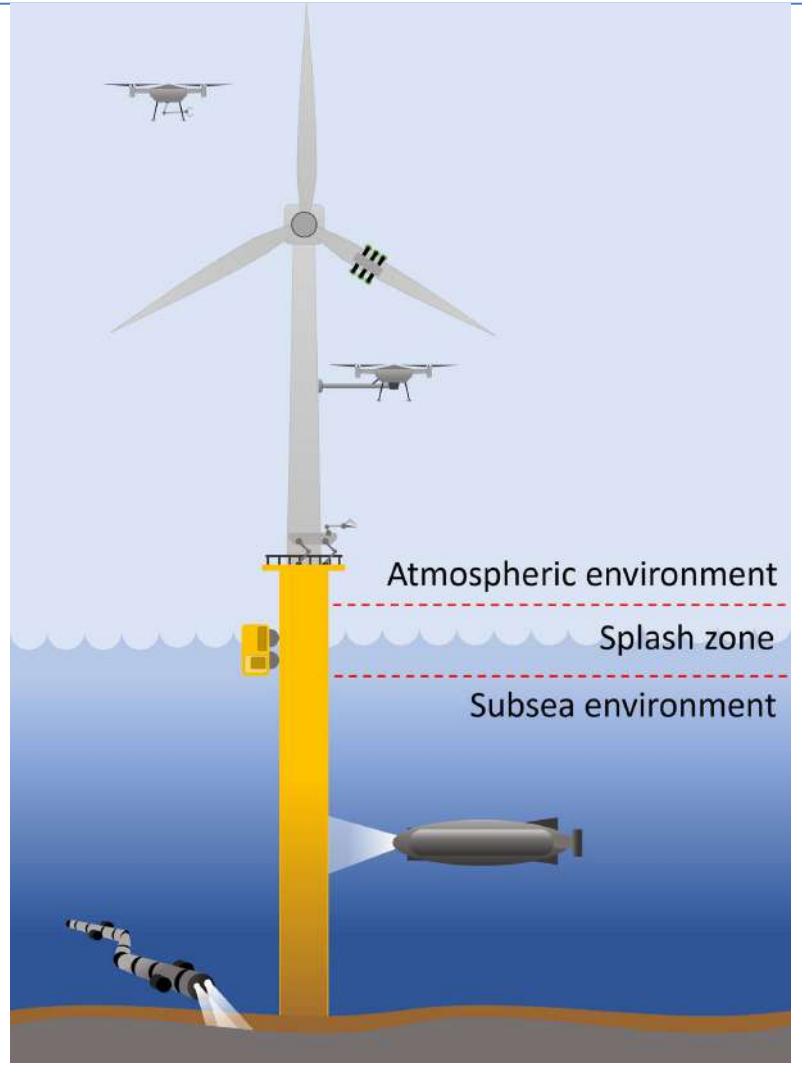
ROBOTICS – Photovoltaic Plants

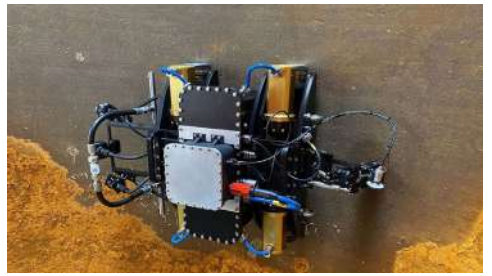
Courtesy: https://hycleaner.de/

ROBOTICS – Photovoltaic Plants

Courtesy: https://hycleaner.de/

ROBOTICS - Windmill





NO AUTONOMY/ NO ADAPTABILTY!!!

Courtesy: https://hycleaner.de/

AI and I&M

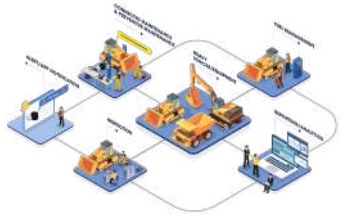
I&M

Wide range of use cases with different requirements

Environments
(manufacturing, assets in the fields)

Production Process
(quality control)

Machines
(components levels, subsystem level, fleet of machines)



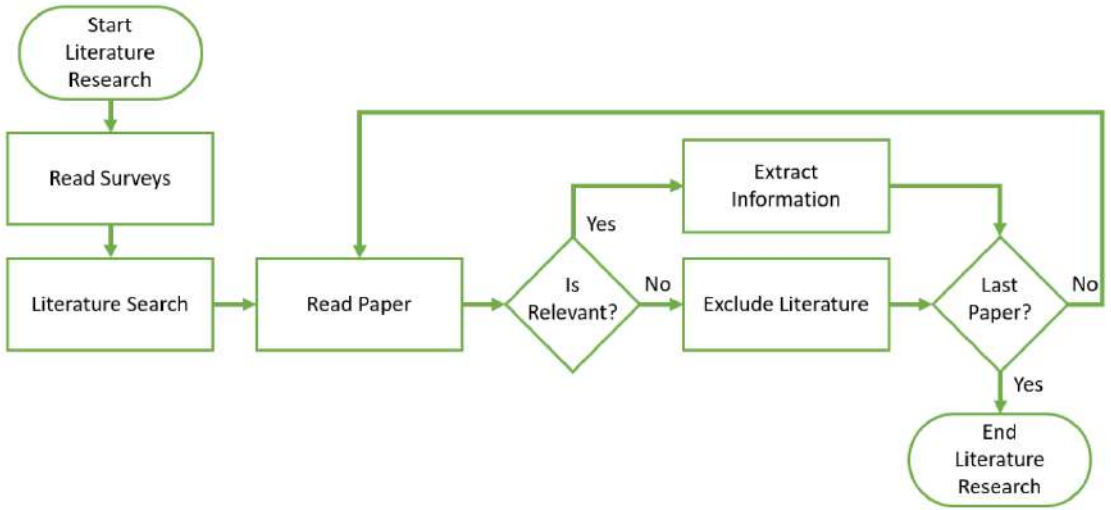
AI and I&M

Technological Challenge:
Anomaly detection for high-speed processes in changing contexts

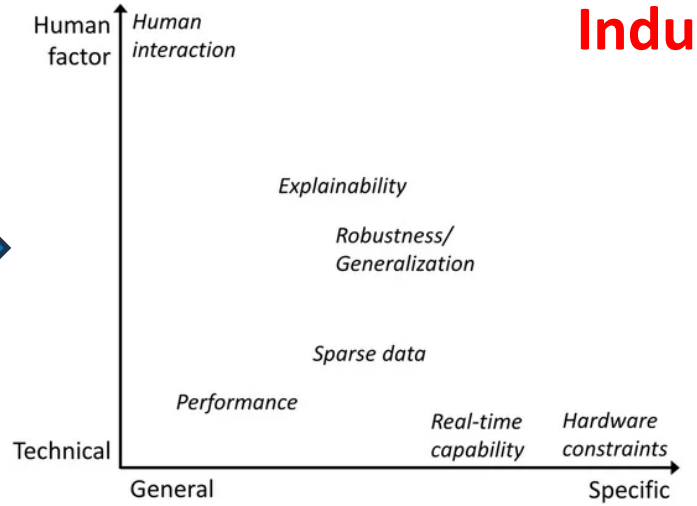
- Anomaly detection for high-speed processes and in high-frequency dynamic system (edge AI)

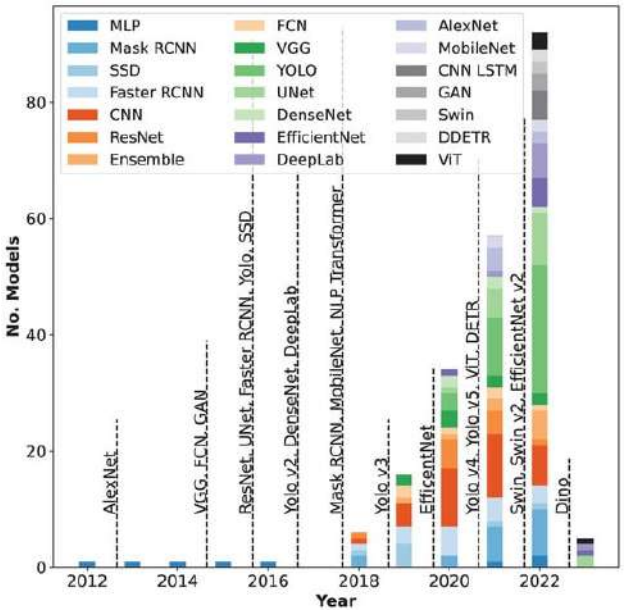

- Anomaly detection in changing contexts

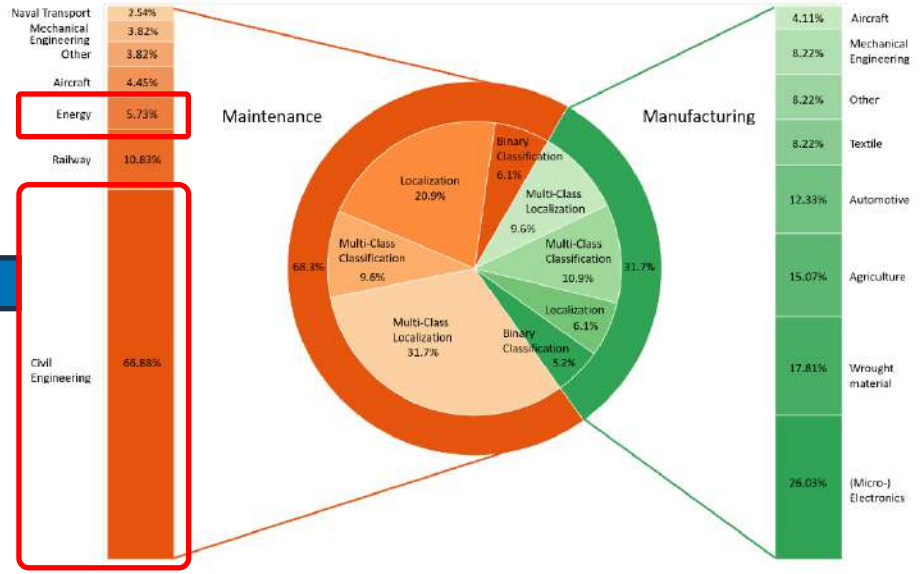

AI and I&M (i.g. Visual Inspection)

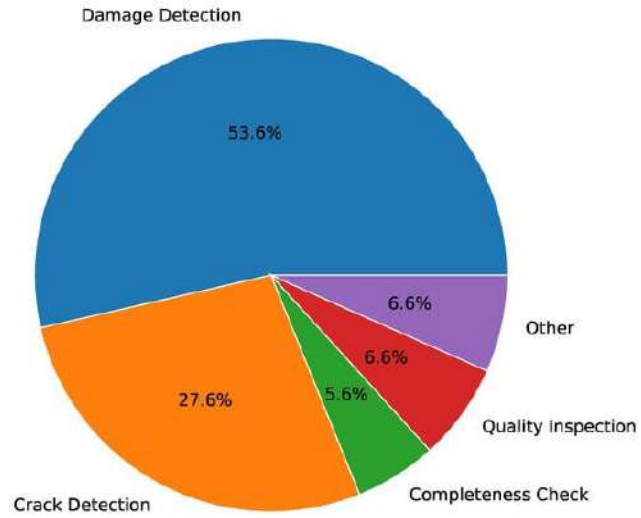


Industrial Application (Maintenance)









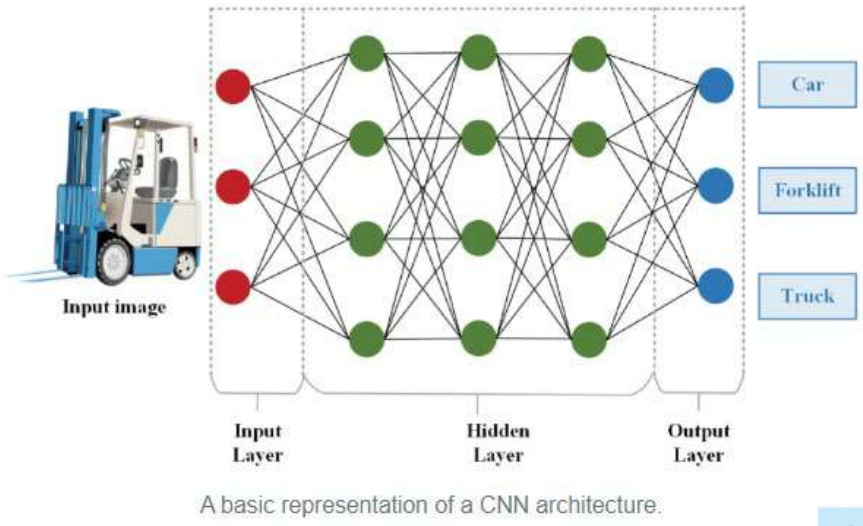
Hütten N. et al. 2024 - Deep Learning for Automated Visual Inspection in….

AI and I&M

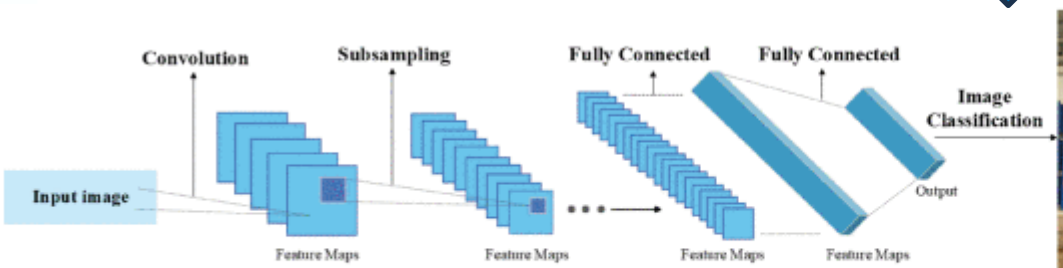
False Positives

NO REPEATIBILTY/ NO RELIABILITY!!!

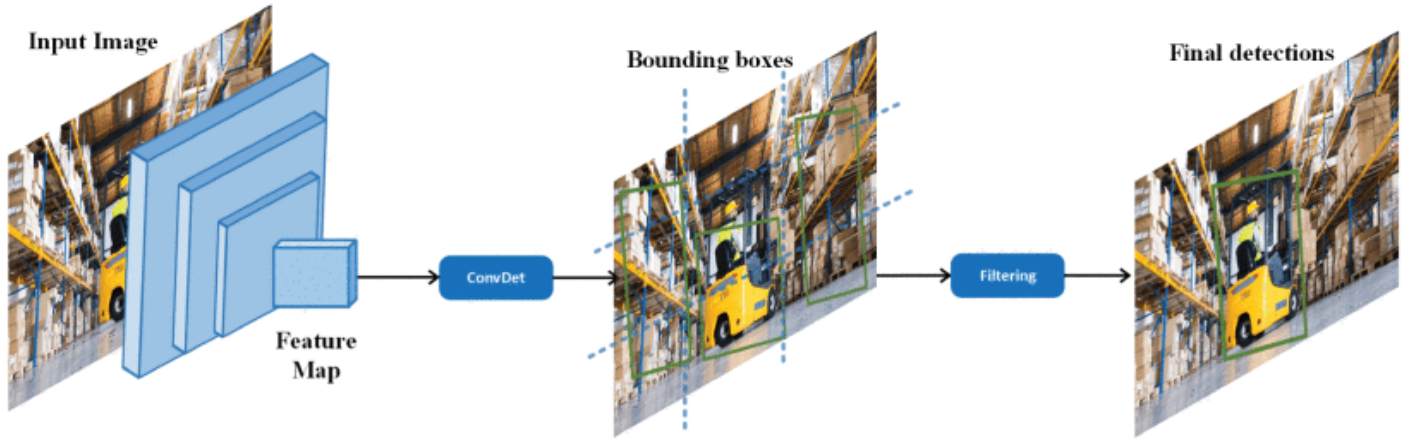
Industrial Application (Logistics)



A basic representation of a CNN architecture.



OBJECT DETECTION



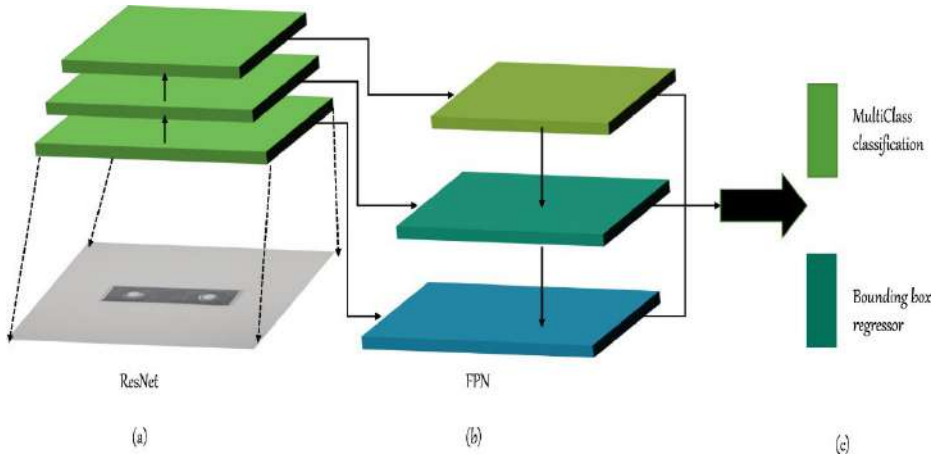
Ameri R. et al. 2024 - A systematic review of….

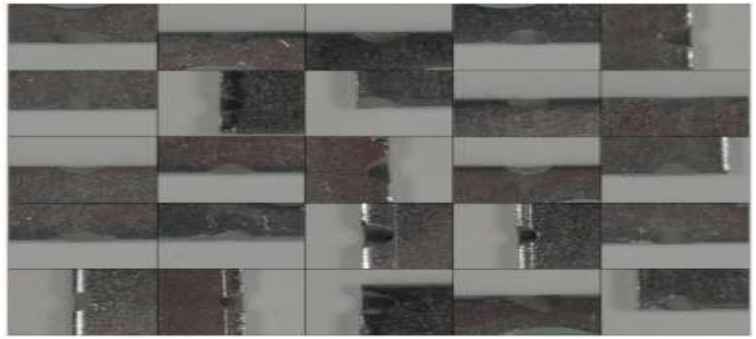
AI and I&M

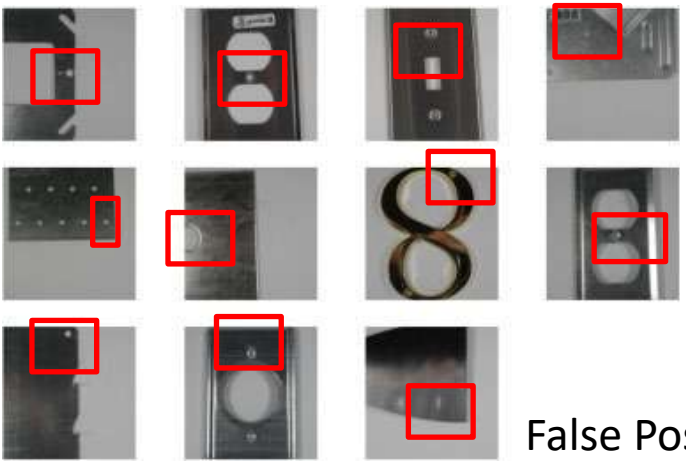
False Positives

NO REPEATIBILTY/ NO RELIABILITY!!!

Industrial Application (Manufacturing)







False Positives

Generic Dataset from Manufacturing Process

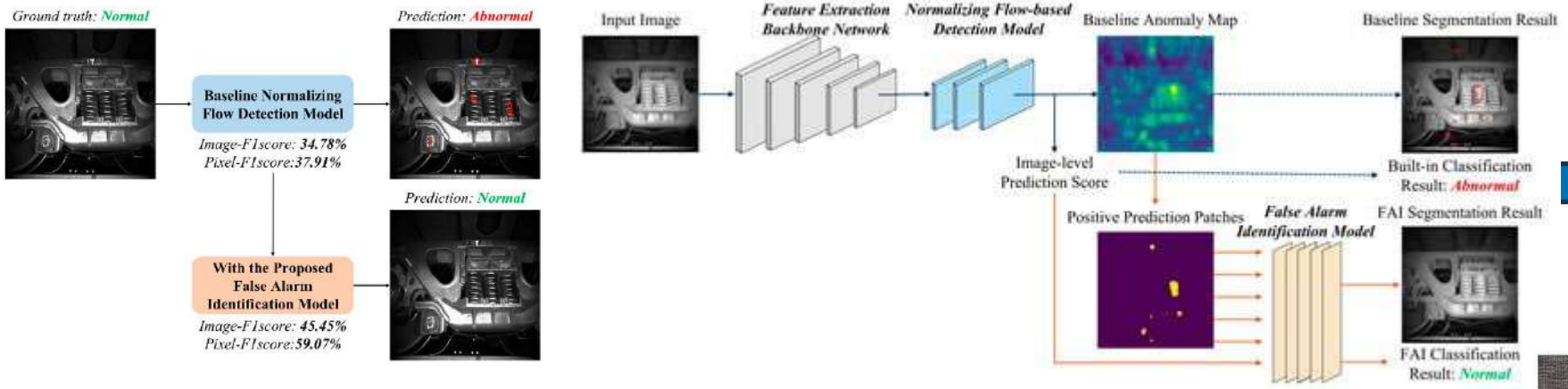
Mezher A. M. et al. 2024 - Computer vision defect detection on…

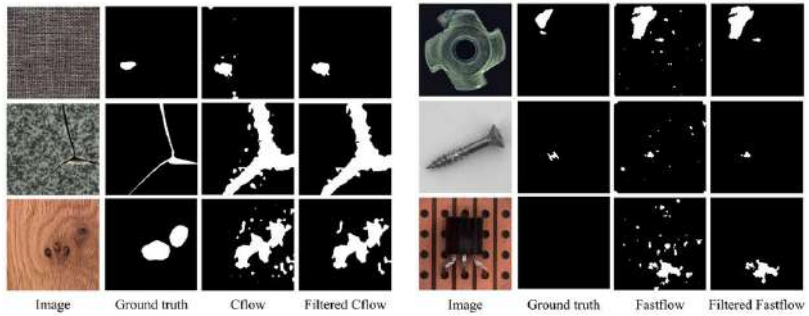
AI and I&M

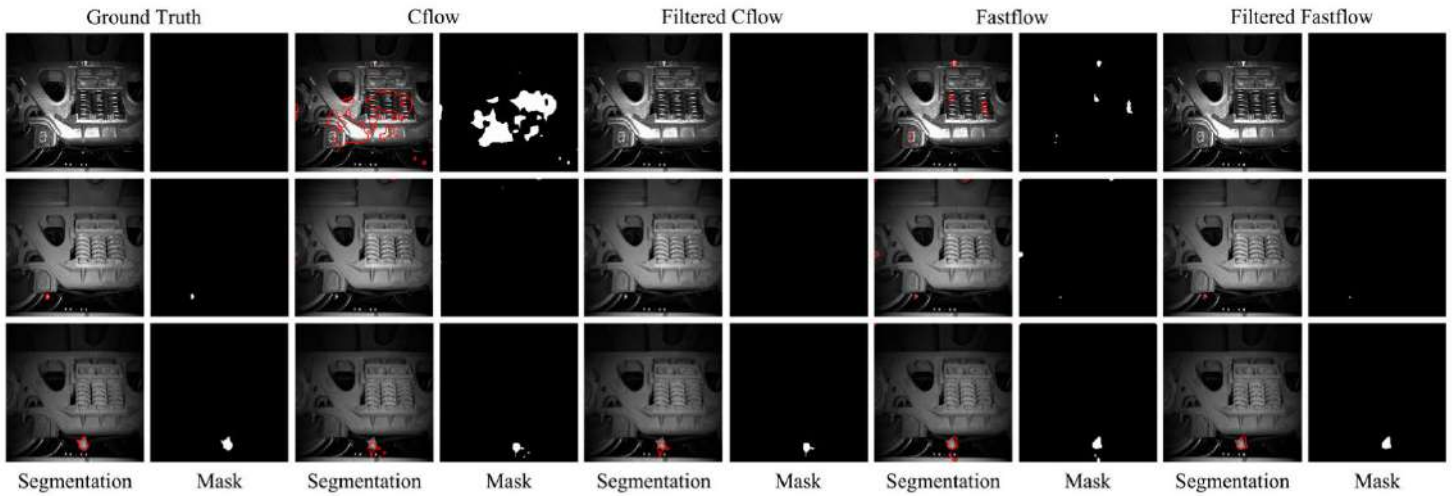
False Positives

NO REPEATIBILTY/ NO RELIABILITY!!!

Transport Application (Trains)







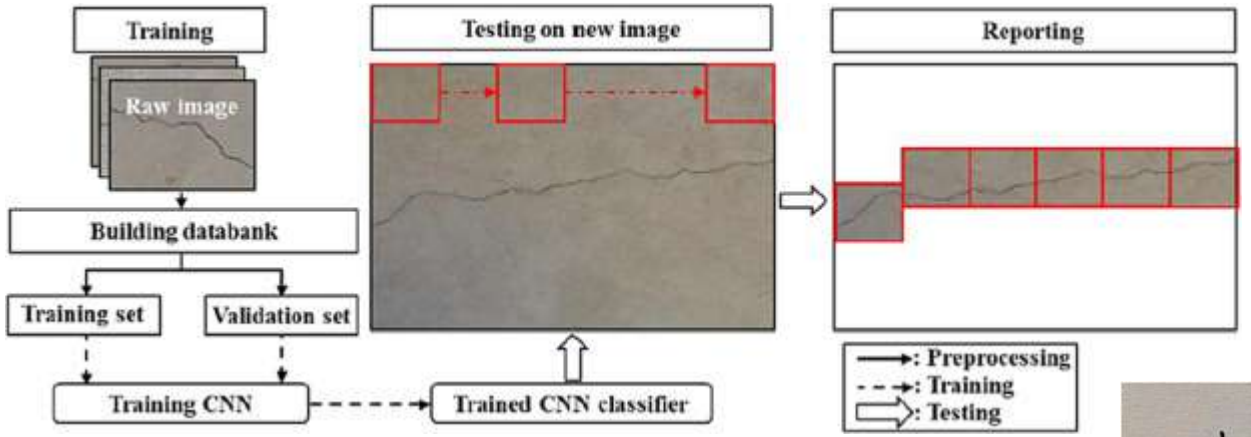
False Positives

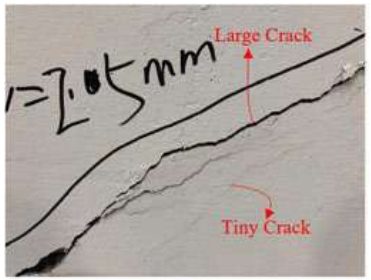
Qiu J. et al. 2023 - Unraveling False Positives in Unsupervised Defect…

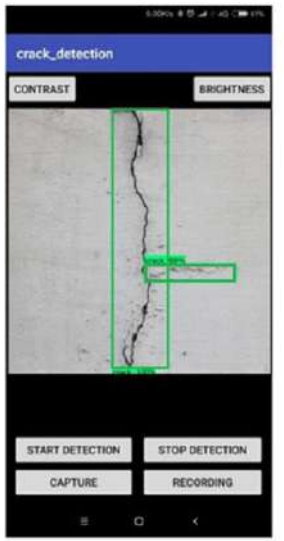
False Positives

NO REPEATIBILTY/ NO RELIABILITY!!!

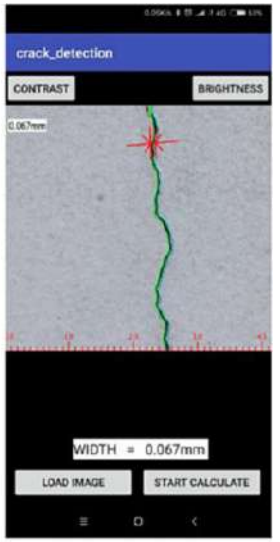
Civil Application (Infrastructures)



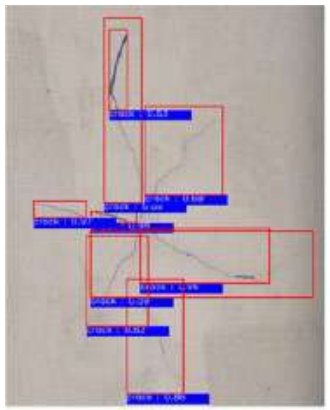




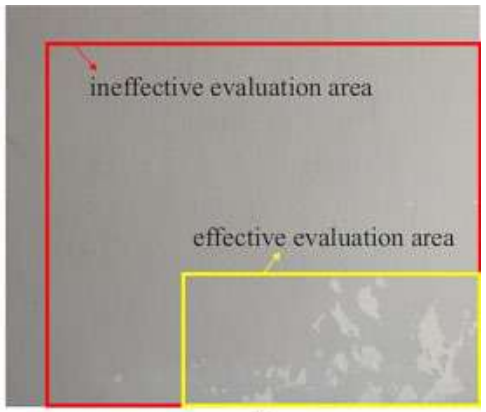
(a)



(b)



(a)



(b)

False Positives

Guo J. et al. 2024 - Surface defect detection of civil structures using images…

CONCLUSIONI (SPUNTI DI RIFLESSIONE)

Investire sulla qualità del montaggio:

- **Montaggio:** garantisce la creazione di un modello di manutenzione predittiva (a priori) molto affidabile e quindi la riduzione delle ispezioni; di conseguenza, aumentando gli intervalli tra un'ispezione e l'altra, le tecnologie di monitoraggio possono esser utilizzate su più impianti e quindi ammortizzarle con più facilità
- **Ispezione:** tecnologie ispettive molto veloci anche se meno accurate per mantenere un'alta frequenza di ispezione e quindi un monitoraggio accurato, in quanto il numero e i range delle incognite sul modello di predizione manutentiva sono molto alte e solo una grande mole di dati (nel tempo) possono "allenare" sufficientemente gli algoritmi e quindi avere delle informazioni abbastanza affidabili per predire i tempi e gli interventi

Riguardo le tecnologie abilitanti, il discrimine potrebbe essere tra la completa autonomia oppure il man-in-the-loop:

- **Autonomia del sistema Robot&AI:**
  - Fully autonomous robot: robot più costosi, ma che permettono l'assenza dell'operatore (se non per la fase di interpretazione finale del potenziale danno)
  - Semi-autonomous robot: robot molto meno costosi, ma che richiedono la presenza dell'operatore in alcune fasi (cambio di area di pannelli solari oppure lo spostamento da una pala all'altra nell'eolico, oppure il cambio di piano di un tunnel ispettivo di una diga, oppure il carico e scarico dei pannelli da montare, il posizionamento della "cartuccera" delle viti, etc.)

Temporalmente, avendo queste tecnologie dei tempi di sviluppo diversi, gli scenari conseguenti potrebbero esser questi:

1. **Brevissimo termine (1-2 anni):**
   a. Montaggio: manuale
   b. Monitoraggio: semi-autonomo

2. **Breve termine (2-3 anni)**
   a. Montaggio: semi-autonomo
   b. Monitoraggio: fully autonomo

3. **Medio-Lungo Termine (3-5-10 anni):**
   a. Montaggio: fully-autonomo
   b. Monitoraggio: fully-autonomo

Energy Plants I&M via Robotics & AI

Roma 7 novembre 2024

Thank you for the attention!

Ferdinando Cannella

ISTITUTO ITALIANO
DI TECNOLOGIA
INDUSTRIAL ROBOTICS FACILITY