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Hey Inspecta! An AI-Enabled Smart Assistant for International Nuclear Safeguards Inspections

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Topics

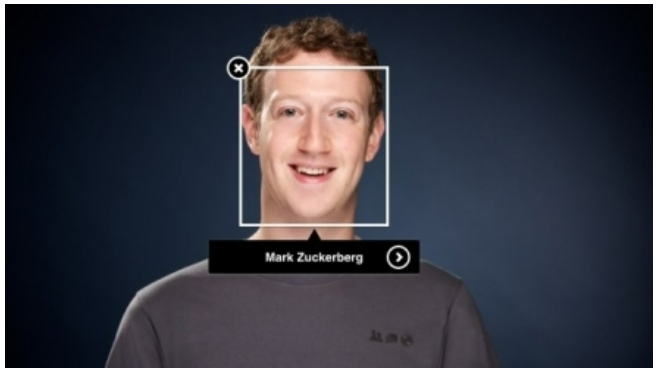
- International nuclear safeguards inspection challenges
- AI and smart digital assistants
- Inspecta concept
- Methodology
  - Safeguards inspection tasks
  - Safeguards challenges
  - Former inspector elicitation
- Technical capabilities and Inspecta skills
- Summary and next steps

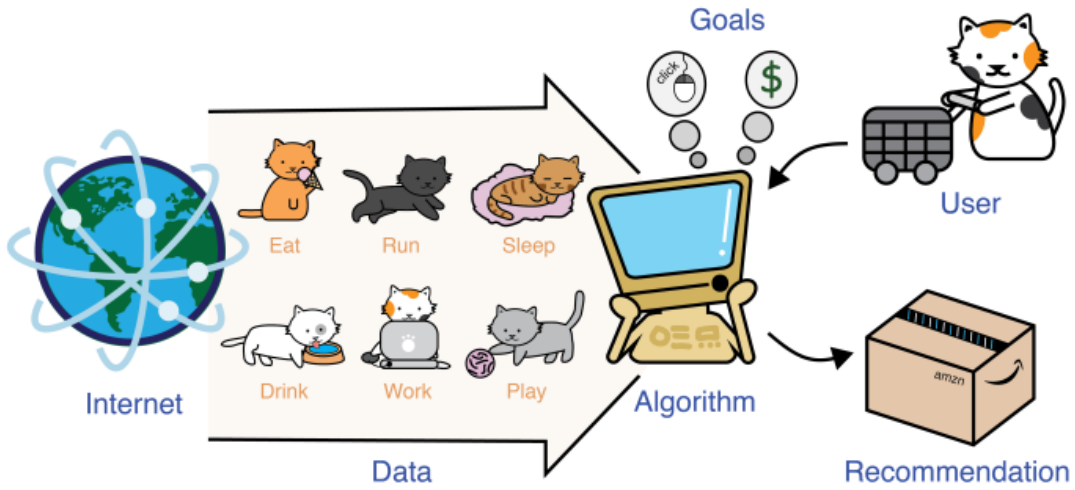
International Nuclear Safeguards (INS) inspections are challenging

Images from https://www.iaea.org/newscenter/multimedia/photoessays/moments-time

Difficult/hazardous environments
Personal Protective Equipment (PPE)
Non-native languages
Physically and mentally challenging
Limited time for activities
Tedious
Jetlag!

Our current world is filled with:





And so much more!

Can we use AI/smart assistants for INS inspections?

- Likely! But what tasks would it do? What would have the most impact on effectiveness and efficiency? What would be allowed? (Think about current AI/smart assistants – what skills have the most impact for your life?)
- NA-22 funded scoping study underway to define what an AI-enabled smart digital assistant for international nuclear safeguards is and what high-impact tasks it may perform
- Inspecta – International Nuclear Safeguards Personal Examination and Containment Tracking Assistant

Hey Inspecta! Verify seals on spent fuel containers in dry storage area. Report to me anything unusual.

Ok, verifying seals in dry storage area. Would you like me to verify all seals or a statistical sample?

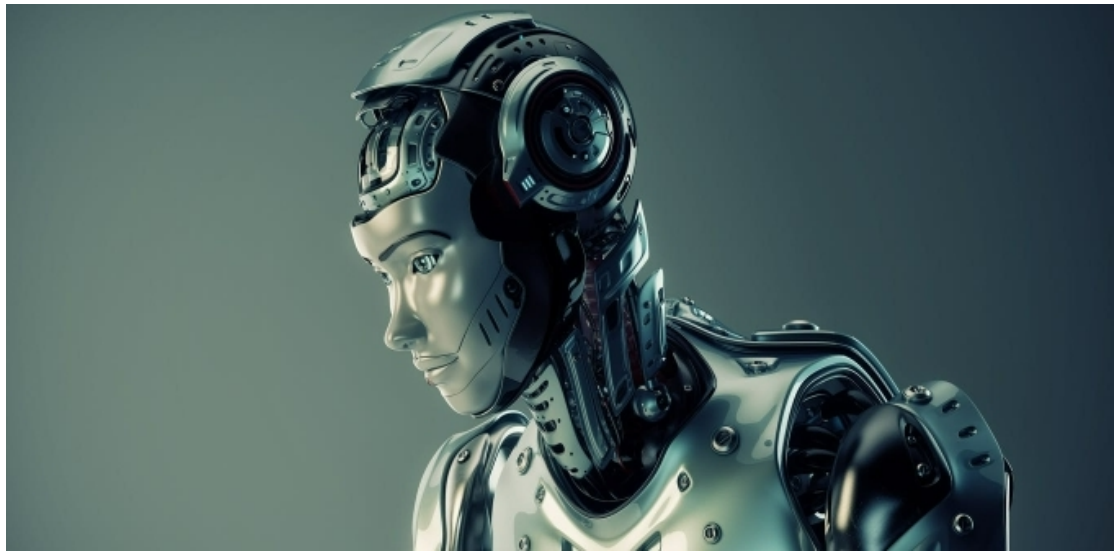
Methodology

List of safeguards inspection tasks

Review IAEA publications to identify challenges

Interview former inspectors and subject matter experts

Most impactful Inspecta “skills” defined
Technical capabilities needed to perform skills



Example task analysis

SG Task	Inspecta Would…	Technical Requirements
Containment/Surveillance (CS)/In-situ Verification of Seals	Map container and seal locations and corresponding information (i.e., identifiers (IDs), attachment date) Inspect seals - (Cobra) Physically attach reader, acquire an image, save image, retrieve reference image, compare to current seal image, note seal ID and compare to expected seal location, pull on wire to confirm attachment, log results.	Digitize facility map or infer/create map based on inspector movements Wayfinding/indoor navigation Image processing (comparing images, anomaly detection, classification) Robotics (line up for image capture, physically connecting reader if needed, pulling on wire) Optical character recognition (OCR) of seal ID and container/item ID

Safeguards challenges

R&D Plan:
T.1.R1 Develop and introduce an integrated system of instrumentation data processing and review, with high level of automation and with unified user interface.

T.1.R2 Develop the Next Generation Surveillance Review software.

T.5.R1 Identify, evaluate and test promising applications of robotics and machine learning/artificial intelligence (ML/AI) to improve the effectiveness and efficiency of safeguards.

2017 Emerging Technologies Workshop:

AI/ML could help achieve further efficiencies and enable inspectors to focus on value added tasks, through automation and by reducing repetitive tasks. It was also noted that such technologies will not replace inspectors.

2020 Emerging Technologies Workshop:

There are challenges in surveillance in how algorithms deal with anomalies vs. novelties

Efficient surveillance review is desired so inspectors can focus on other tasks

Robotics could be a consideration for use with spent nuclear fuel verification

Inspector elicitation

- Research team conducted scripted interviews with eight former IAEA safeguards inspectors and individuals with highly relevant experience in facility operations and nuclear materials control
- Interview questions were designed to elicit the identification of high-impact inspection tasks that Inspecta could potentially assist with
- Tasks identified as most challenging, tedious, or prone to human error

(1) Surveillance review

Image: Fournier / IAEA, 2016

(2) PIVs, in general

Image: IAEA, 2016

(3) Transcription

(4) Integrating information

(5) Seals

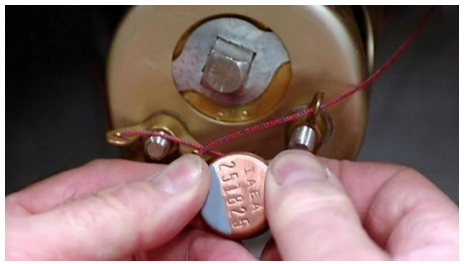


Image: IAEA 2020

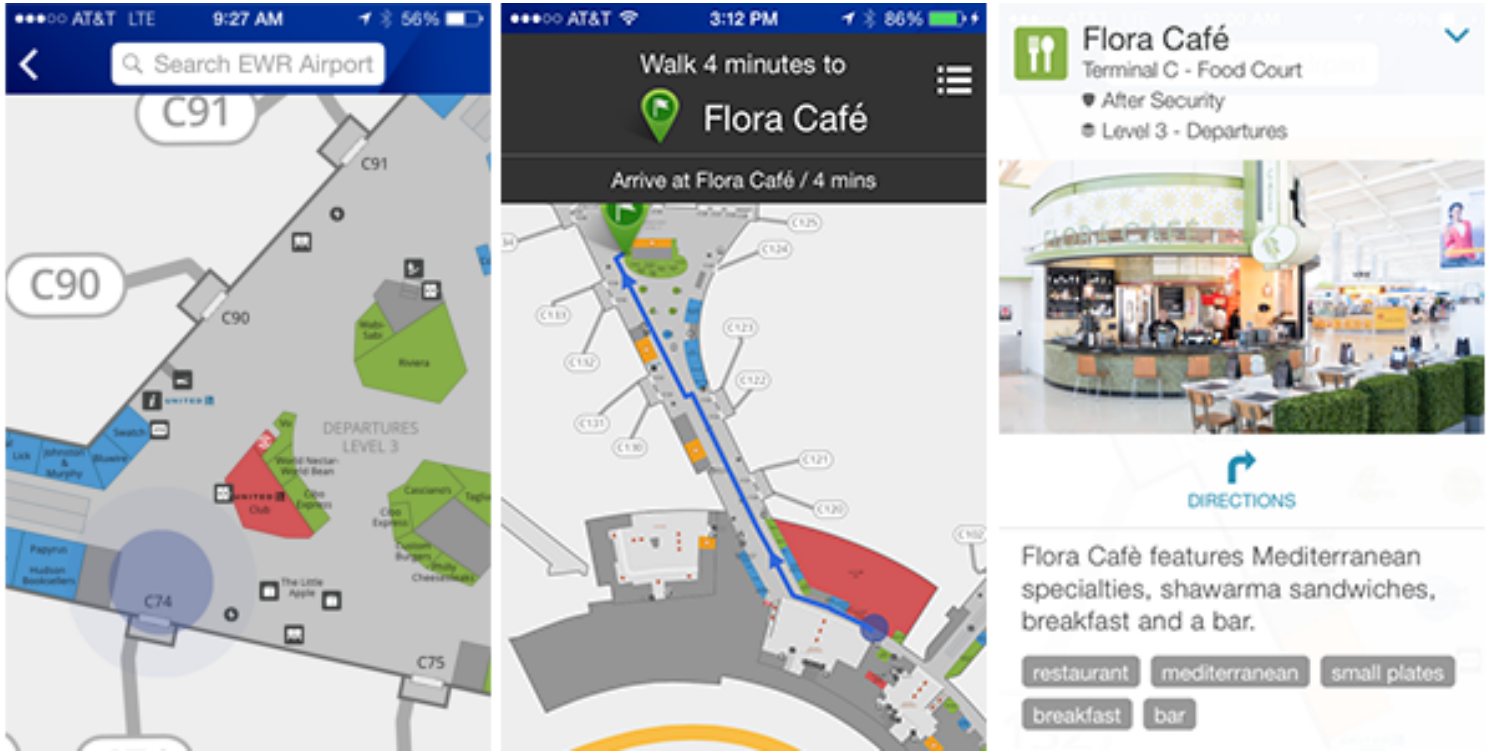
(6) Spent fuel verification

IAEA Inspectors using ICVD to detect Cerenkov glow from Spent Fuel Assemblies: Typical Cerenkov glow from VVER fuel seen in inserted photograph

Image: IAEA 2019

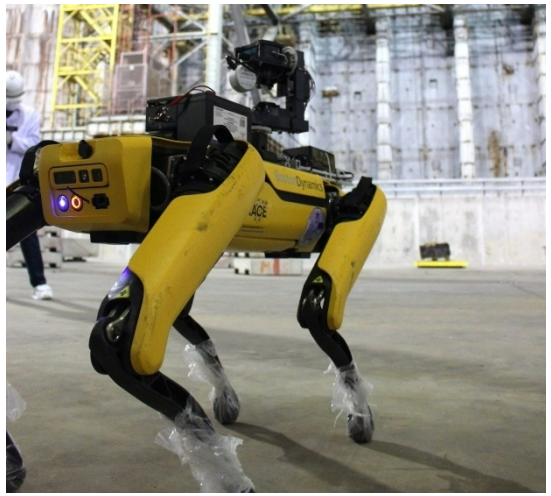
Technical capabilities to support Inspecta “skills” include:

Indoor navigation

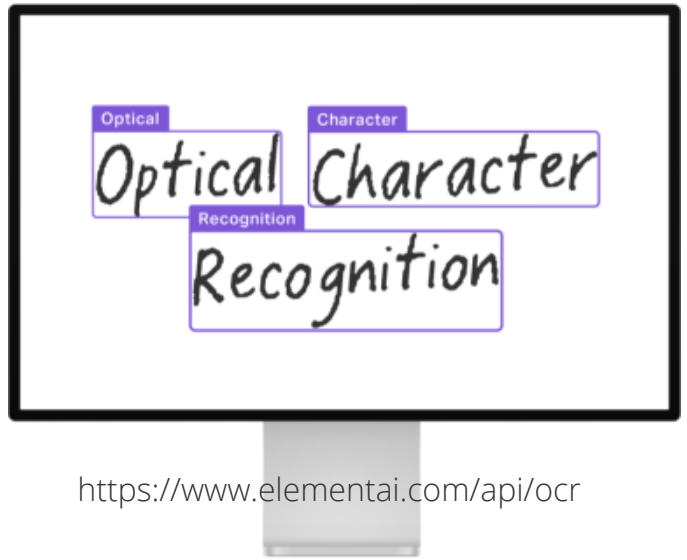


https://www.futuretravelexperience.com/2015/08/united-adds-indoor-maps-and-beacon-based-wayfinding-to-app/

Robotics

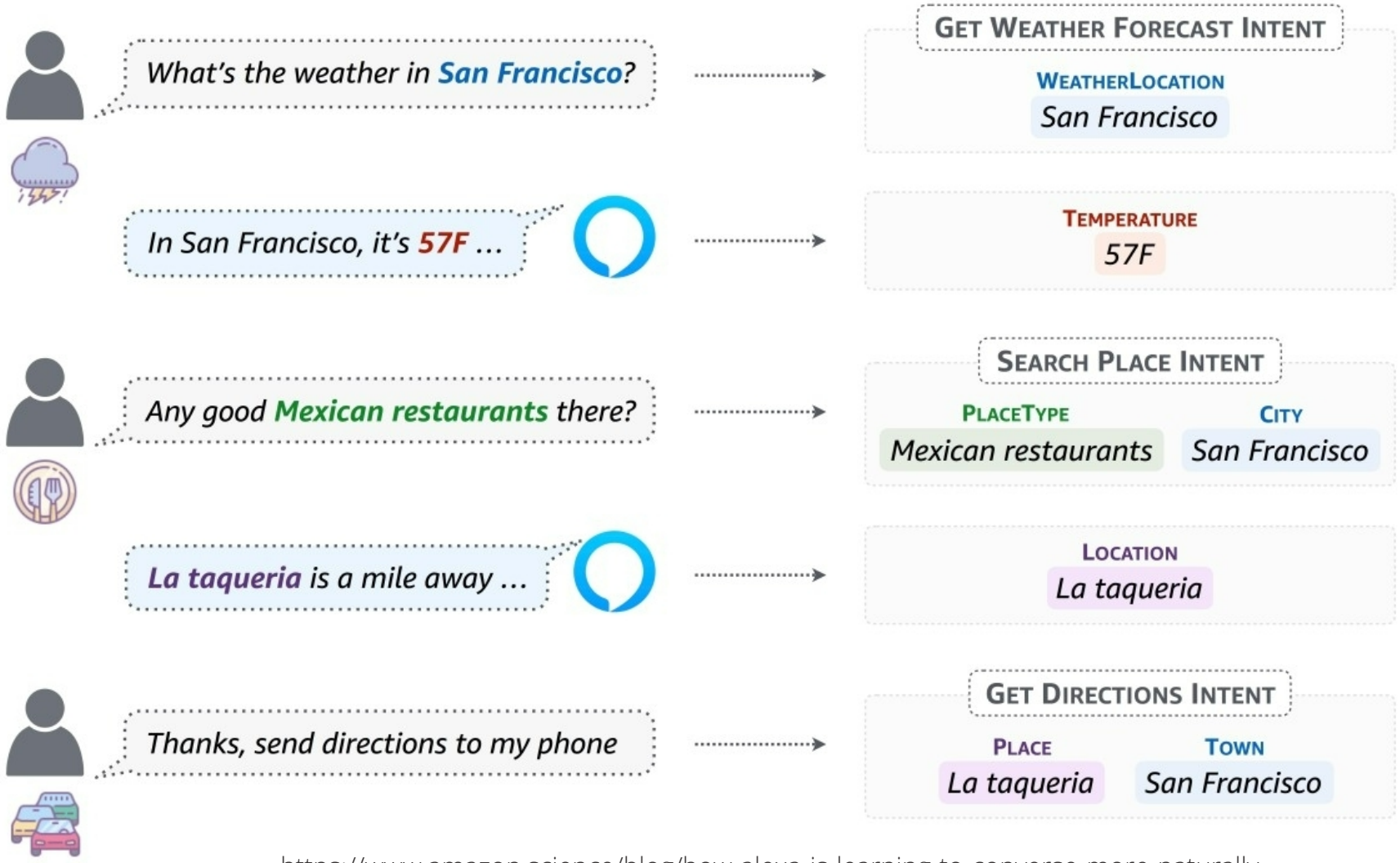


https://spectrum.ieee.org/automaton/robotics/robotics-hardware/boston-dynamics-spot-Chernobyl



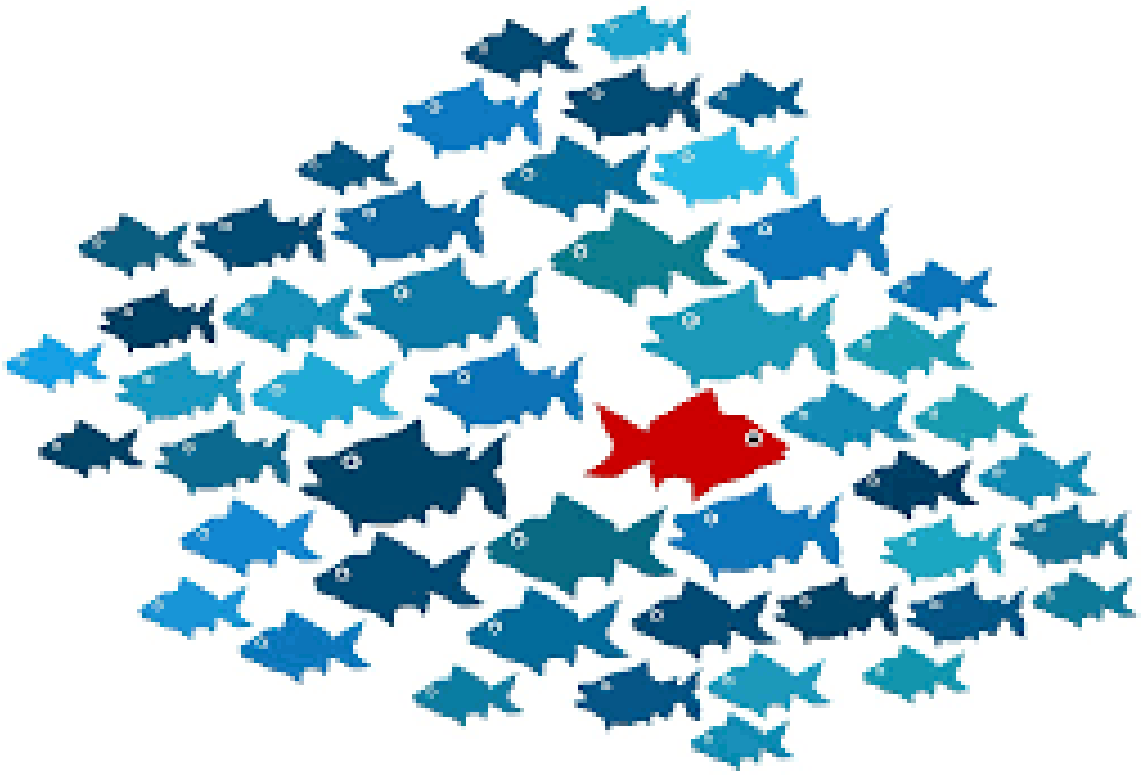
https://www.elementai.com/api/ocr

Information recall, speech synthesis, voice-to-text

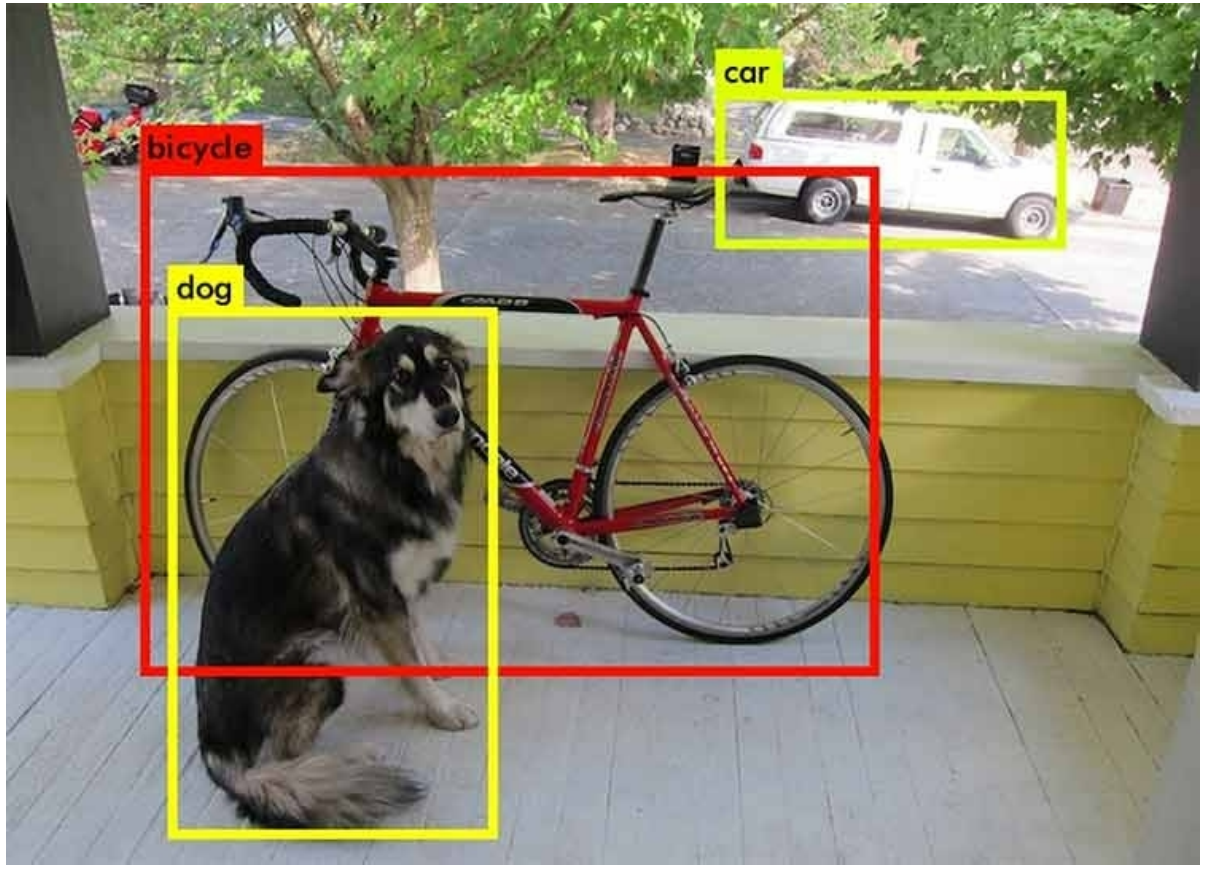


https://www.amazon.science/blog/how-alexa-is-learning-to-converse-more-naturally

Anomaly detection and object identification



https://thedatascientist.com/anomaly-detection-why-you-need-it/



https://www.techleer.com/articles/123-google-to-help-developers-in-object-identification-using-tensorflow-object-detection-api/

Research team is currently determining state-of-art of these technical capabilities

Example: Spent fuel verification

1) Inspectors stand on bridge over spent fuel pool

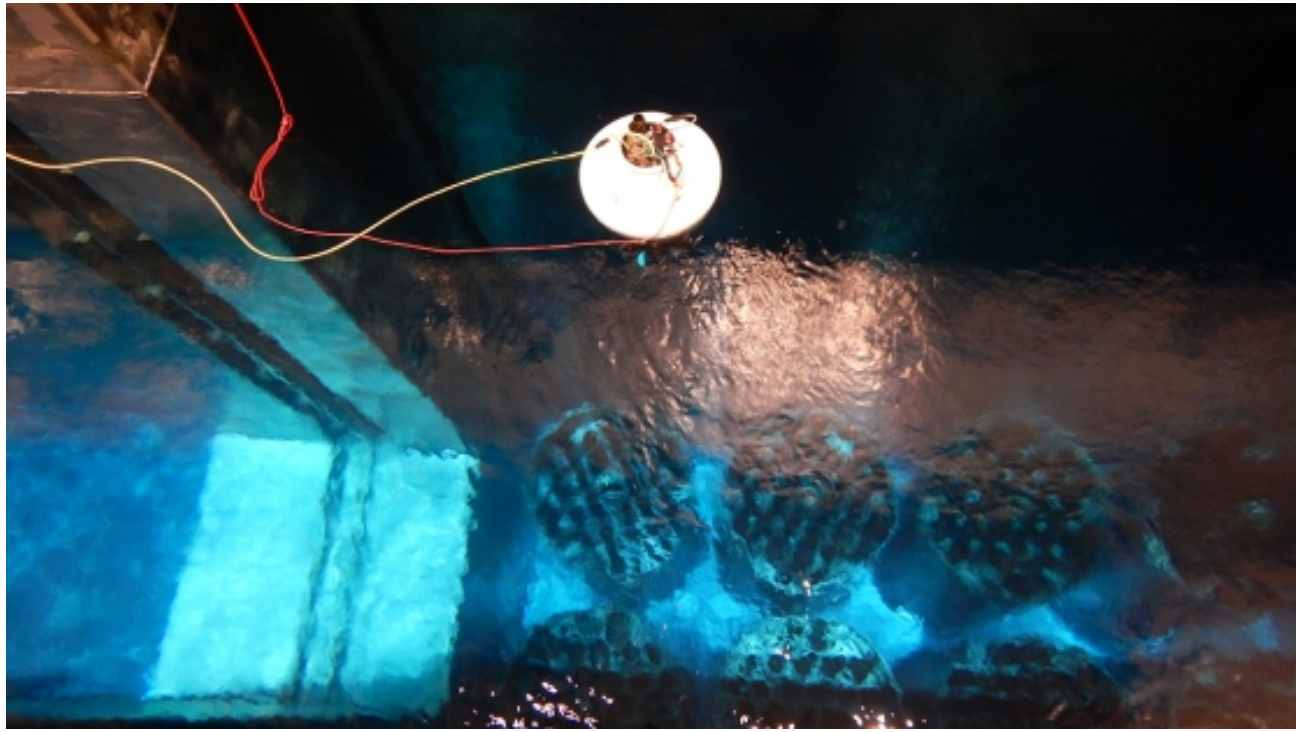
2) Inspector 1 confirms the presence of the spent fuel in the pool (ICVD)

3) Inspector 2 marks results on map of spent fuel pool

IAEA Inspectors using ICVD to detect Cerenkov glow from Spent Fuel Assemblies: Typical Cerenkov glow from VVER fuel seen in inserted photograph

Image: IAEA 2019

Example: Spent fuel verification



1) Robot navigates bridge or floats atop the spent fuel pool

2) ICVD collects images & pool location

3) Algorithm compares data with declaration, and historical data.

4) Reports information to inspector.

Image: Adem Mutluer/IAEA, 2019

Conclusion and next steps

- Integrating AI/smart assistants with INS inspection workflows has the potential to reduce inspection burden (for both inspector and facility), increase efficiency and increase effectiveness
- Team is researching state-of-art of technical capabilities required to support Inspecta skills
- Skills based on results of methodology (tasks, IAEA published challenges, inspector interviews) AND technical capabilities that are available in the near term
- Development of a prototype may begin as early as October 2021