SAND2020-6365C

# Industry's Use of Deep Learning, and Implications for International Safeguards

*Presented By:*

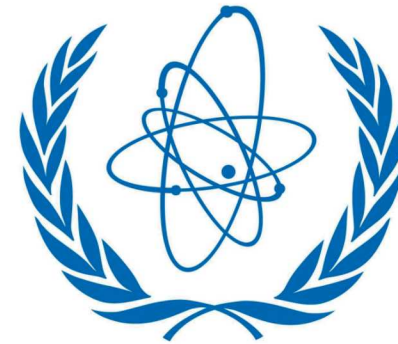Michael Higgins, Zoe Gastelum

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# Outline

- Motivation

- DL in Industry and Safeguards
  - Classification
  - Image Segmentation
  - Pattern Recognition
  - Image Generation and Enhancement
  - Natural Language Processing (NLP)

- Conclusions

# Motivation

- The amount of information safeguards inspectors and analysts are required to assess is growing while resources to assess the information stay constant.

- Deep learning models could facilitate safeguards inspections and analyses.

- MLDL has been used across many industries for classification, segmentation, regression, and NLP to improve QoL. The goal is to further understand how these applications could be used for international safeguards.
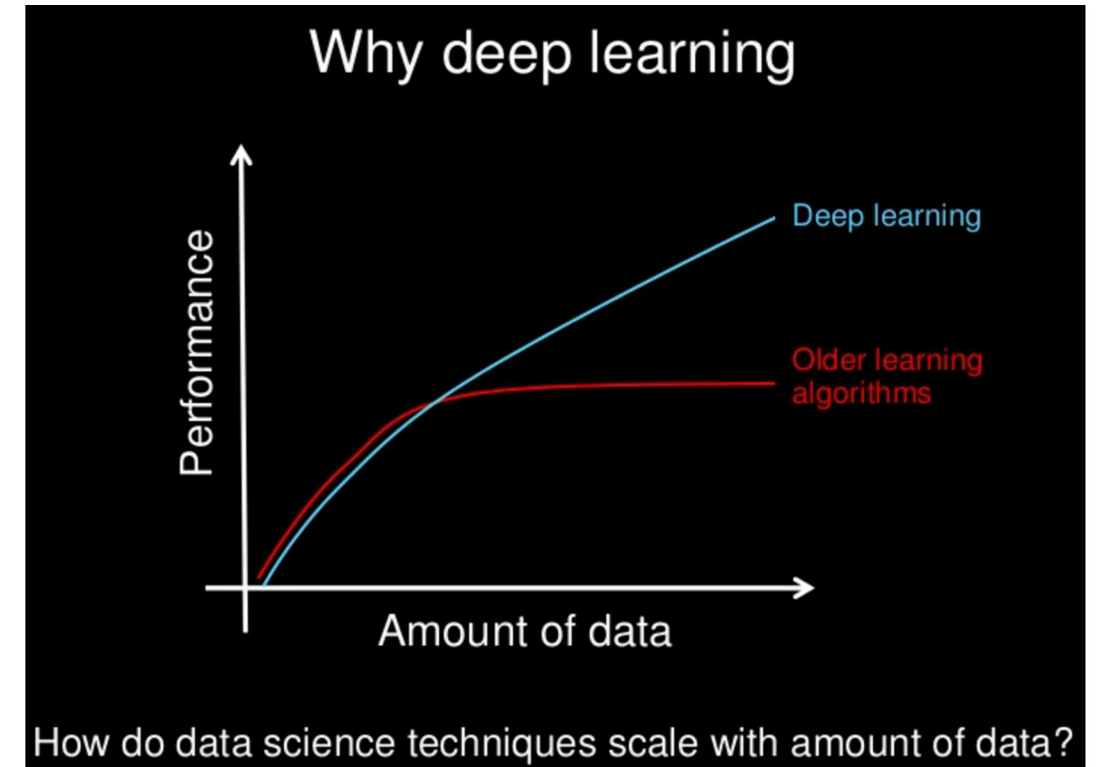


**IAEA**
**International Atomic Energy Agency**

# What is Deep Learning?

- Deep Learning (DL) is a subfield of machine learning focused on algorithms inspired by the structure and function of a brain called neural networks.

- Andrew Ng, founder of Google Brain, described deep learning as
  - "Making algorithms better and easier to use"
  - "Making revolutionary advances in machine learning and artificial intelligence"
  - "Believes that deep learning is the best shot at progressing towards real AI"

- A key feature of DL algorithms is that they are scalable. Scalable means that with increasing data and large neural network configurations the performance of the model increases.

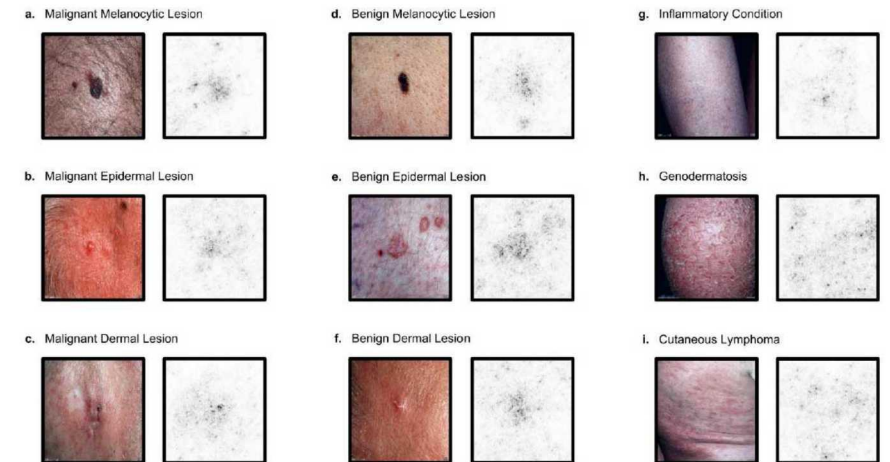- DL algorithms are the key choice for data analysis of modern companies.



[1] Why Deep Learning? A presentation given by Andrew Ng

# DL is commonly used for...

- Classification

- Object Detection and Segmentation

- Pattern Recognition and Anomaly Detection

- Image Generation and Enhancement

- Natural Language Processing (NLP)

# Classification

- A model's goal is to identify a subject into pre-defined categories.

- Classification models are used on images, audio, or sensor data.

- Industry Examples:
  - *Medicine.* Dermatology utilizes image classification for the automatic identification of skin conditions, focusing on finding cancer.
  - *Law.* Classification is used to predict case outcome, which supports their decisions to take on a case.
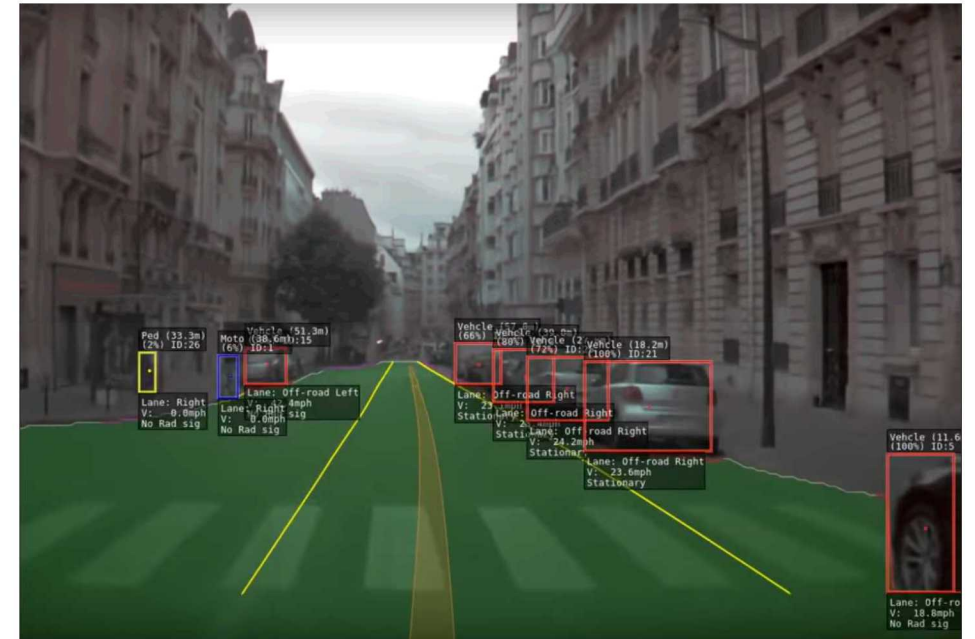


[2] (Esteva et al. 2017)

# Classification for International Safeguards

- Image classification could be developed as a preliminary measure for tamper indication on TIDs.

- Flag frames of surveillance footage which contain an object of interest.

- Automatic tagging to organize internal image collection by fuel cycle step or equipment.

- Text classification tools could be developed to identify the step of the Physical Model to which technical publications are most relevant.

- Current Work:
  - *Text.* R&D work is being done to modify, by training on 1.5 million DOE OSTI documents, BERT to classify journal articles related to the nuclear field. ([3] Fortin, CoDa 2020 poster)
  - *Image.* R&D work has been done to determine from images if a nuclear power plant is operating. ([4] Gastelum, Shead, JNMM 2018)

# Object Detection and Segmentation

- Object detection models place a bounding box, mask, or visual indicator around an object.

- Image segmentation can be applied to a few objects of interest or segmentation and classification of an entire image.

- Segmentation is primarily used on video and images.

- Industry Examples:
  - *Agriculture.* image segmentation is used for apple sorting and grading and to identify potato blight by using image segmentation on the potato plant's leaves
  - *Security.* facial recognition software is being used by the police and the Chinese government has used facial recognition to monitor minorities.
  - *Transportation.* the automotive industry uses image segmentation models to improve the ability of self-driving cars.



[5] "Paris Streets in the Eyes of Tesla Autopilot - YouTube" n.d.

# Object Detection and Segmentation for International Safeguards

- Image segmentation on safeguards surveillance camera data could be used to identify the presence and movement of key pieces of equipment or containers housing nuclear materials.

- Analysts could implement object detection models to locate and segment buildings or externally visible equipment with satellite images.

- Open source analysts could use object detection to locate key indicators in highly complex, cluttered, or obscured visual fields.

- Current Work:
  - *Video.* Cui is developing a system using video surveillance for object-based identification of nuclear-related objects. [6] (Cui. 2018 osti.gov)

# Pattern Recognition and Anomaly Detection

- Pattern Recognition and Anomaly Detection are processes used to determine normal behavior and highlight behavior outside the norm.

- Pattern Recognition is used across all data types: text, image, video, and data.

- Industry Examples
  - *Medical.* pattern recognition is used to search for cancer, using input from human white blood cells and the five types of cancer cells
  - *Finance.* The finance industry uses pattern recognition and anomaly detection models to detect fraudulent activities on bank accounts.
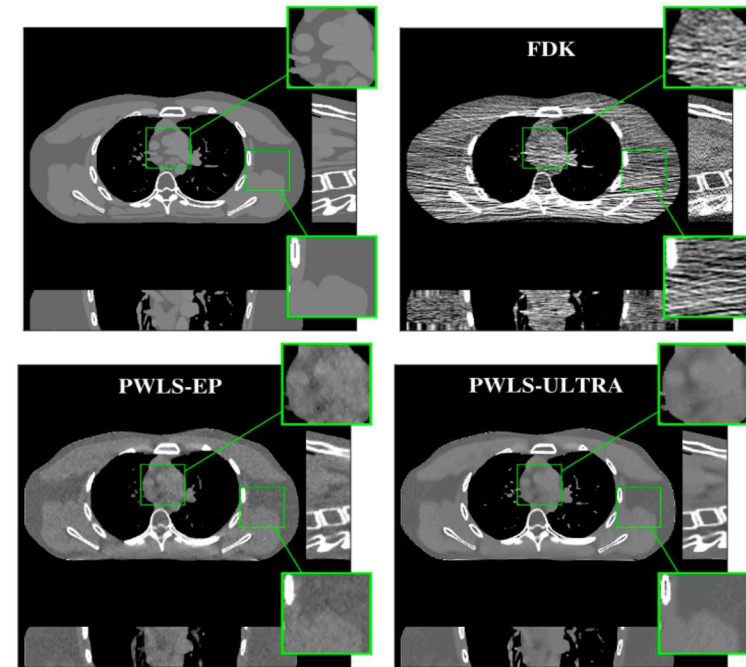
# Pattern Recognition and Anomaly Detection for International Safeguards

- Inspectors could use anomaly detection to support review of surveillance data.

- Pattern recognition algorithms might be applied to sensors deployed in a facility to detect drift from calibration or inconsistencies between disparate sensors.

- Analysts could potentially use anomaly detection algorithms to monitor sources or technical publication streams for new topics, changes in word use, or arrivals and departures of new authors.

- Current Work:
  - *Satellite Images.* R&D is using Google Earth to identify changes at nuclear facilities. ([7] Rutkowski, JNMM 2018)
  - *Data.* R&D work on anomaly detection for radiation measurements is currently being worked on.  ([8] Popoola, CoDA 2020 Poster)
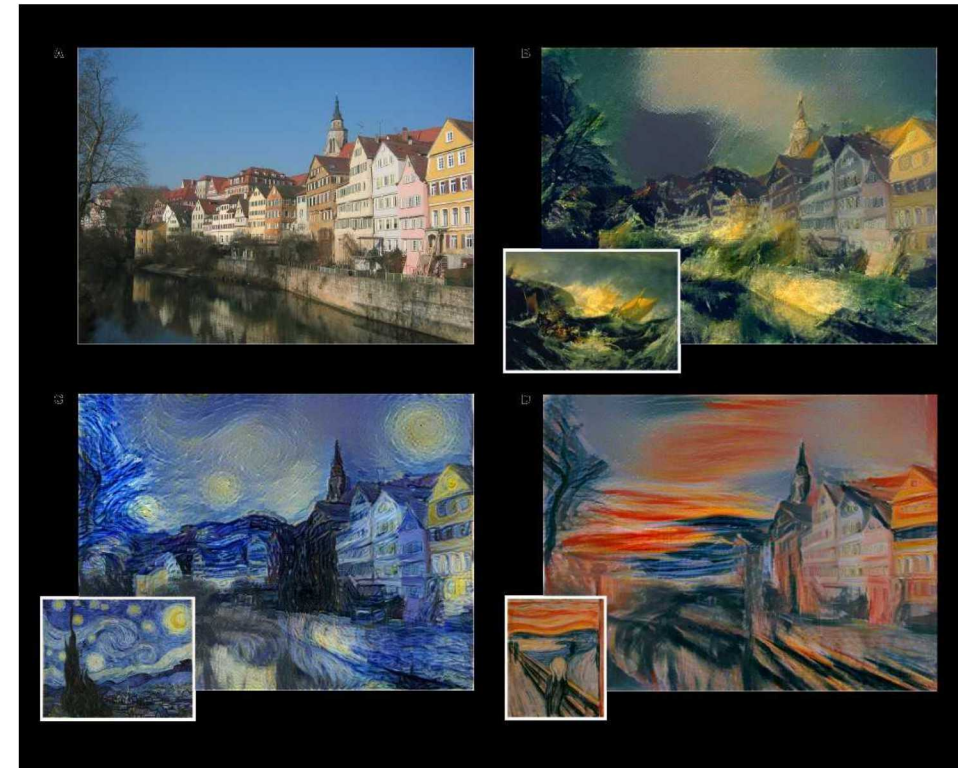
# Image Generation and Enhancement

- Image Generation and Enhancement are processes used to improve the quality of images or videos.

- This process can include removing regions of an image, reconstruct an image, or improve the resolution of the image.

- Industry Examples:
  - *Medicine:* reconstruction techniques are used for analysis; this includes the synthesis of a ROI and the second technique uses a dictionary to improve image quality.
  - Security. Security proposes using enhancement and style transfer techniques to improve the quality of images. Image enhancement of luggage going through X-ray machines to aid TA's searches has been proposed.



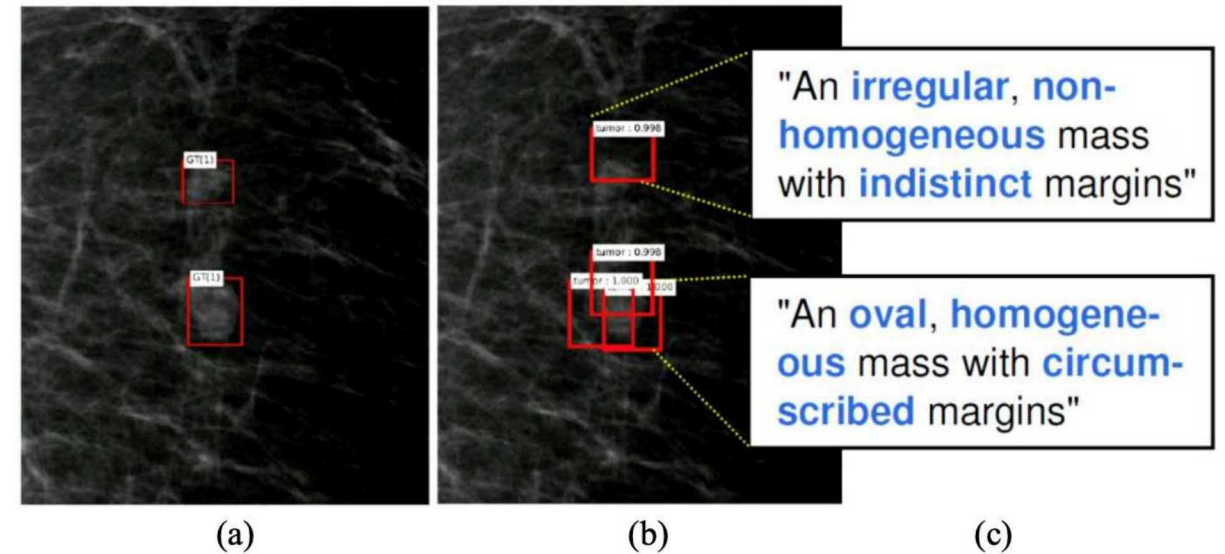([9] Ravishankar, Ye, and Fessler 2020)

# Image Generation and Enhancement for International Safeguards

- Analysts could use image enhancement to improve image quality of resolution of open source images.

- Satellite imagery analysts could use image enhancement to improve the quality of grainy images when atmospheric conditions make it difficult to see.

- Image generation could be used to improve the size of datasets to improve the quality of DL models.
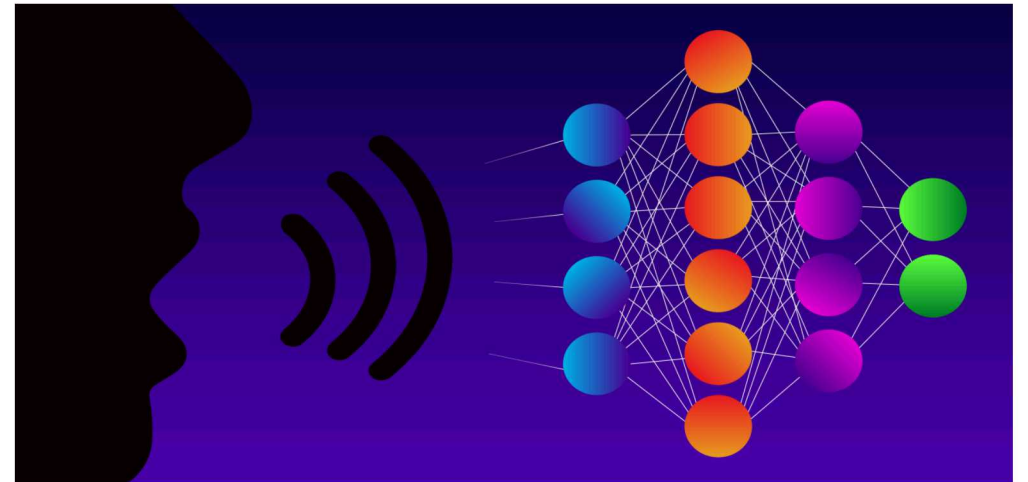
# Natural Language Processing

- NLP consists of the application of statistical and computer algorithms in order to process human-understandable language

- NLP is further broken into the following tasks: machine translation, captioning, question and answer, and information retrieval.

- NLP is primarily used for text, video, and audio files.

- Industry Examples:
  - *Medicine.* The medical community has proposed using captioning for automatic detection and description of tumors.
  - *Law.* An IBM Watson based model is able to answer common law questions and help customers fill out basic legal forms.



"An **irregular, non-homogeneous** mass with **indistinct** margins"

"An **oval, homogeneous** mass with **circumscribed** margins"

(a)　　　　(b)　　　　(c)

[10] Kisilev et al. 2011

# NLP

- International Safeguards:
  - Inspectors could use captioning models to caption the images taken in the field, or images from safeguard sensors.
  - Open source safeguards analysts confront the challenge of mislabeled or unlabeled images. Captioning algorithms could support better search and processing of open source images.

- Current Work:
  - *Multiple Datatypes.* Feldman has proposed an information retrieval system on opensource datatypes to identify nuclear related work ([11] Feldman, JNMM 2018)

# Conclusions

- Enhancements to computing power and architecture increase the performance of DL models and has brought us into the current age of AI popularity.

- DL models have been adopted across many industries to the point where ordinary citizens may be interacting with AI on a daily basis without knowing it.

- Based on these advances we believe that international safeguards may be able to adopt some of these practices.

- R&D is already being conducted for several DL applications to safeguards. We think there may be even more opportunities.

# Questions?

# References

[1]  A. Ng, "Andrew Ng, Chief Scientist at Baidu," 2015. https://www.youtube.com/watch?v=O0VN0pGgBZM.

[2]  A. Esteva *et al.*, "Dermatologist-level classification of skin cancer with deep neural networks," *Nature*, vol. 542, no. 7639, pp. 115–118, Feb. 2017, doi: 10.1038/nature21056.

[3] Fortin, Daniel. "CoDa." *NukeBERT: A Nuclear Domain BERT Model for Improved Natural Language Processing Tasks in Nuclear Nonproliferation*, 2020.

[4]  Inferring the Operational Status of Nuclear Facilities with Convolutional Neural Networks to Support International Safeguards Verification

[5]  "Paris streets in the eyes of Tesla Autopilot - YouTube." https://www.youtube.com/watch?v=_1MHGUC_BzQ.

[6]  Y. Cui, "Using Deep Machine Learning to Conduct Object-Based Identification and Motion Detection on Safeguards Video Surveillance," 2018. [Online]. Available: https://www.osti.gov/servlets/purl/146602.

[7]  Rutkowski, Joshua, et al. "Site Monitoring with Sentinel-1 Dual Polarization SAR 48 Imagery Using Google Earth Engine." *JNMM*, 2018, pp. 48–59.

[8]  Popoola, Gabriel A. "CoDa." *Using Anomaly Detection for Activity Identification*.

[9]  S. Ravishankar, J. C. Ye, and J. A. Fessler, "Image Reconstruction: From Sparsity to Data-Adaptive Methods and Machine Learning," *Proc. IEEE*, vol. 108, no. 1, pp. 86–109, 2020, doi: 10.1109/JPROC.2019.2936204.

[10] P. Kisilev, E. Sason, E. Barkan, and S. Hashoul, "Medical image captioning: learning to describe medical image findings using multi-task-loss CNN," p. 1, 2011, [Online]. Available: https://dlpm2016.fbk.eu/docs/kisilev_learning.pdf.

[11] Feldman, Yana, et al. "Toward a Multimodal-Deep Learning Retrieval System for Monitoring Nuclear Proliferation Activities." *JNMM*, XLVI, no. Number 3, 2018, pp. 68–80.