Machine Intelligence

Beyond Neural Networks

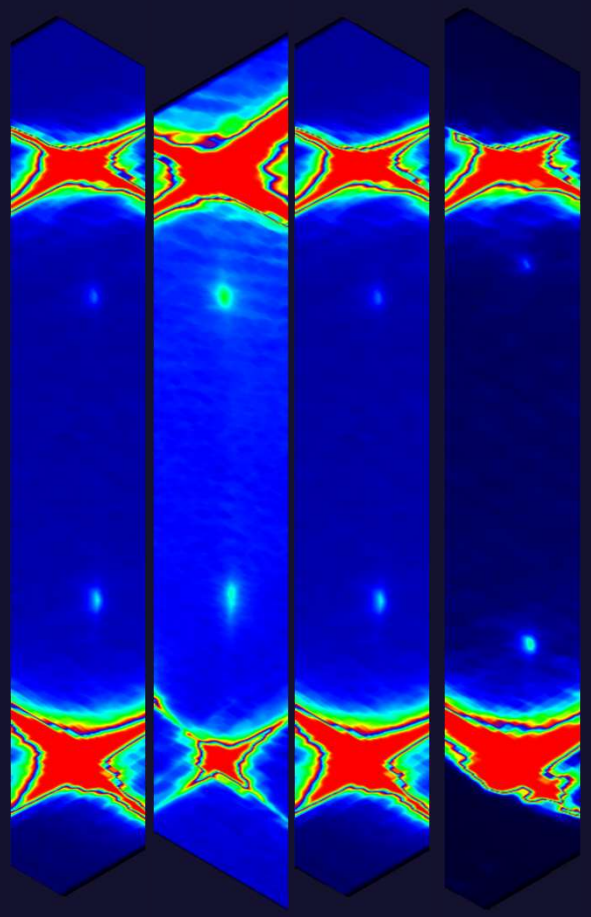
Alternative AIs for NDT

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Introduction

Machine Intelligence

- Started Machine Intelligence in 2012
- Developing AI technology
  - spin off from academic research
- Consultancy: control, vision, measurement, software
  - manufacturing and science sectors



(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Why use AI in NDT?

Machine Intelligence

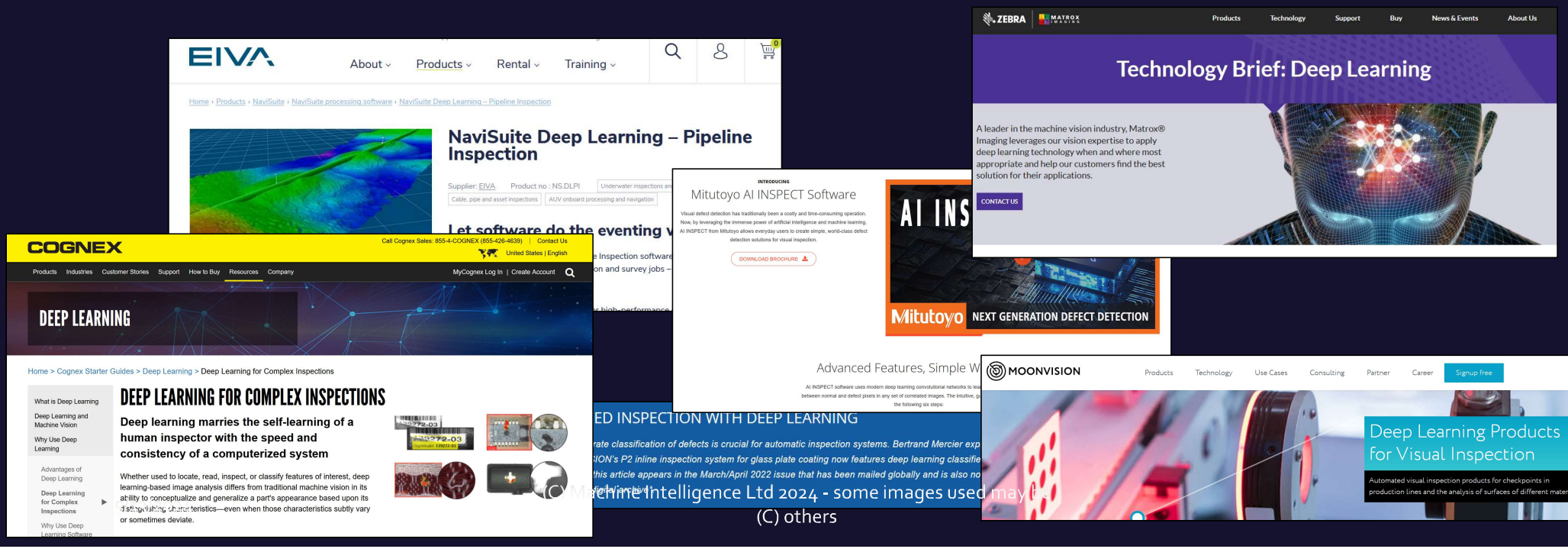
- Automating (or augmenting) some task
  - When the data is complex, non-obvious or as a shortcut
- Use data
  - Detect: e.g. Is there a visible defect?
  - Classify: e.g. Is it a scratch or pitting?
- Make sense of data
  - Learn from: e.g. What parameters effect the product quality?
  - Understand: e.g. What is the relationship between temperature and porosity?

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

AI in NDT

Machine Intelligence

- Current state of the art is Deep Learning and Neural Networks
  - Majority of advertising seems to suggest that this is all there is…

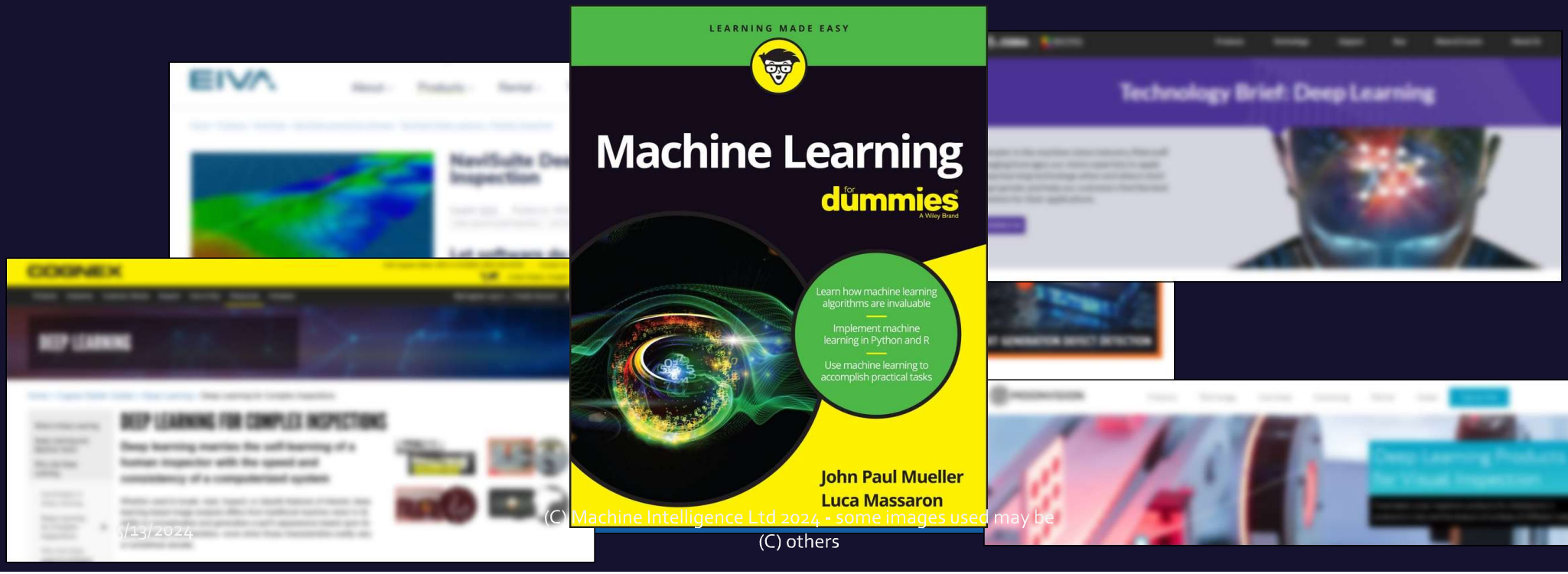


(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

AI in NDT

Machine Intelligence

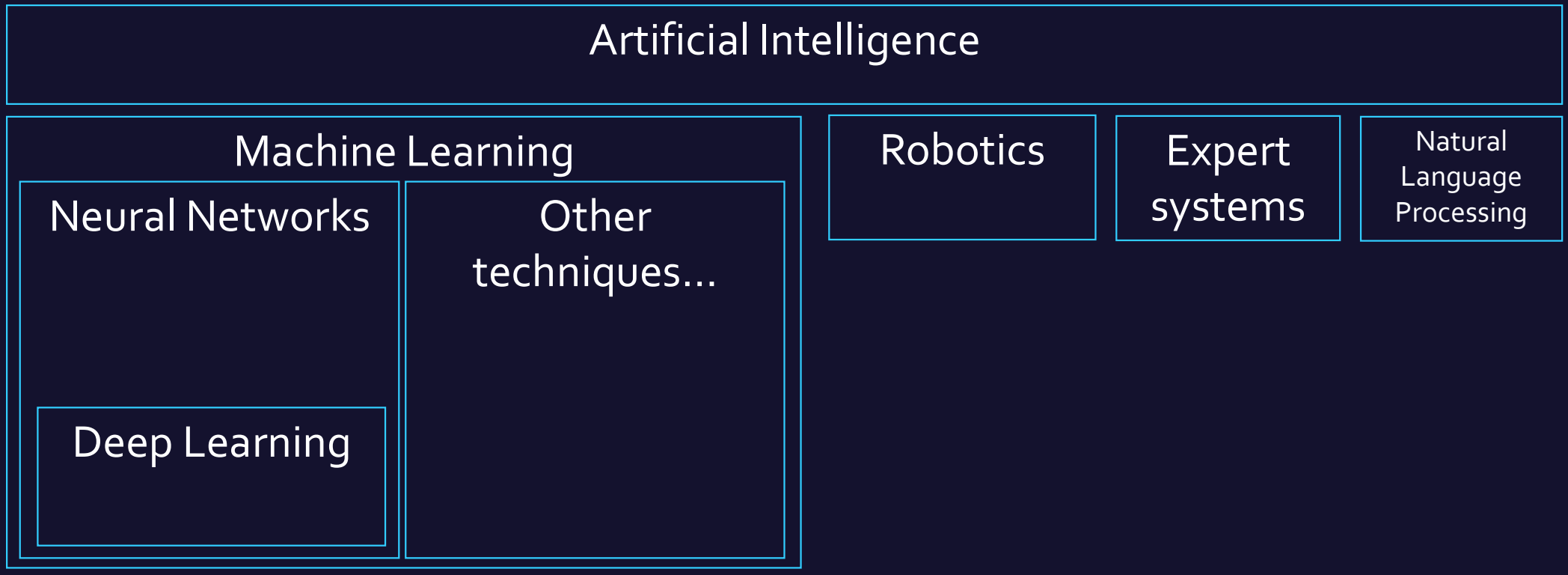
- Current state of the art is Deep Learning and Neural Networks
  - Majority of advertising seems to suggest that this is all there is…



(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Defining some terms

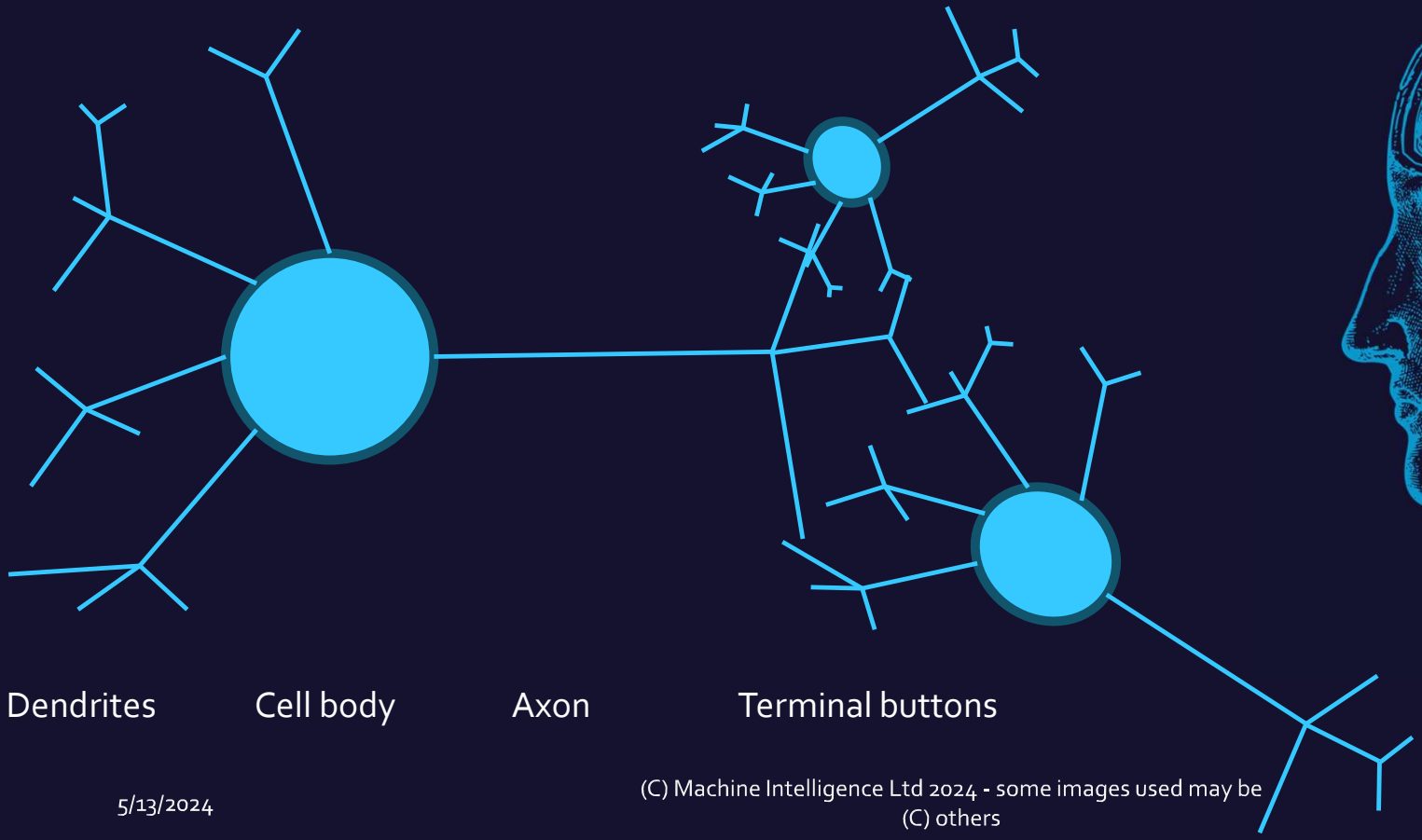
Machine Intelligence

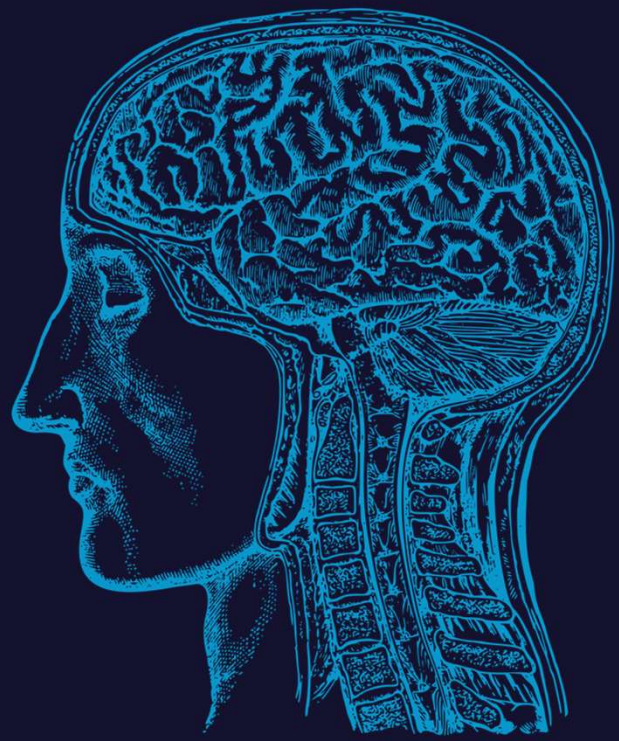


(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

What is a Neural Network?

Machine Intelligence

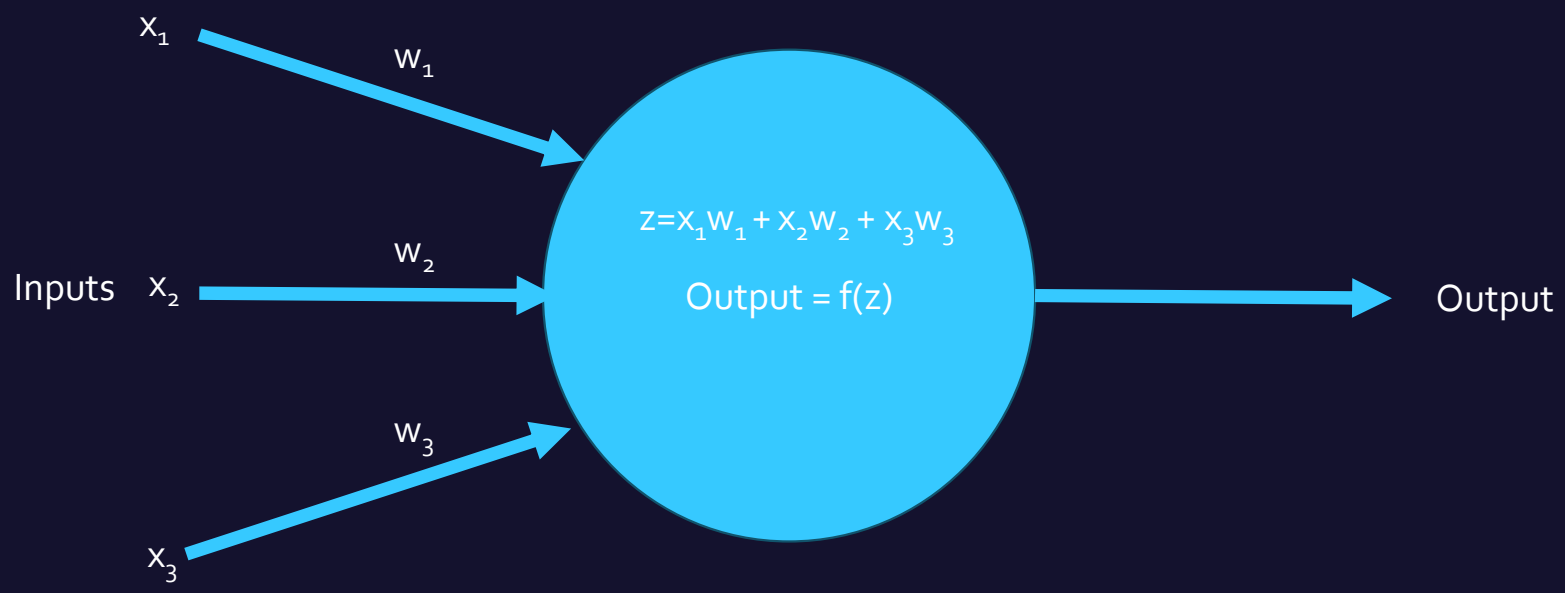




Dendrites Cell body Axon Terminal buttons

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

What is a Neural Network?

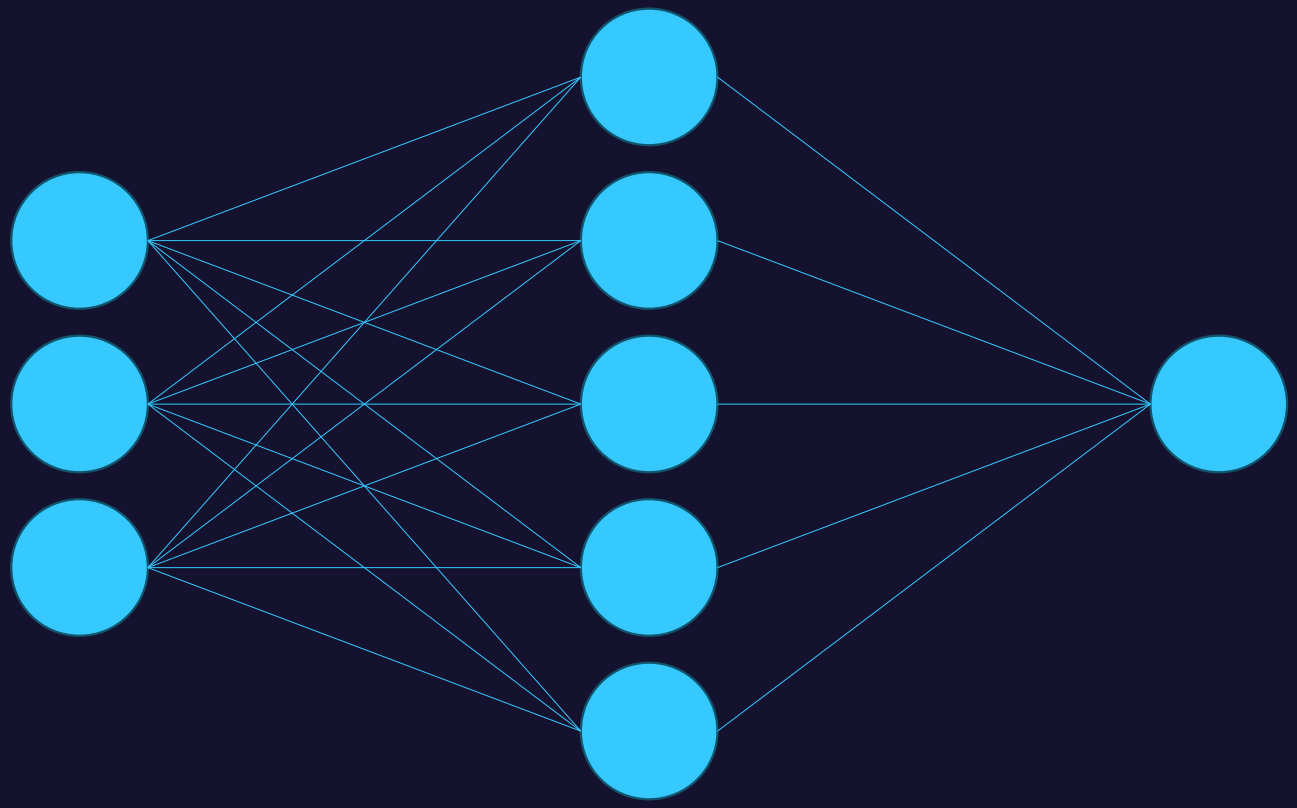


(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

* f(z) depends on usage. Often sigmoid function

What is a Neural Network?

Machine Intelligence



Input layer

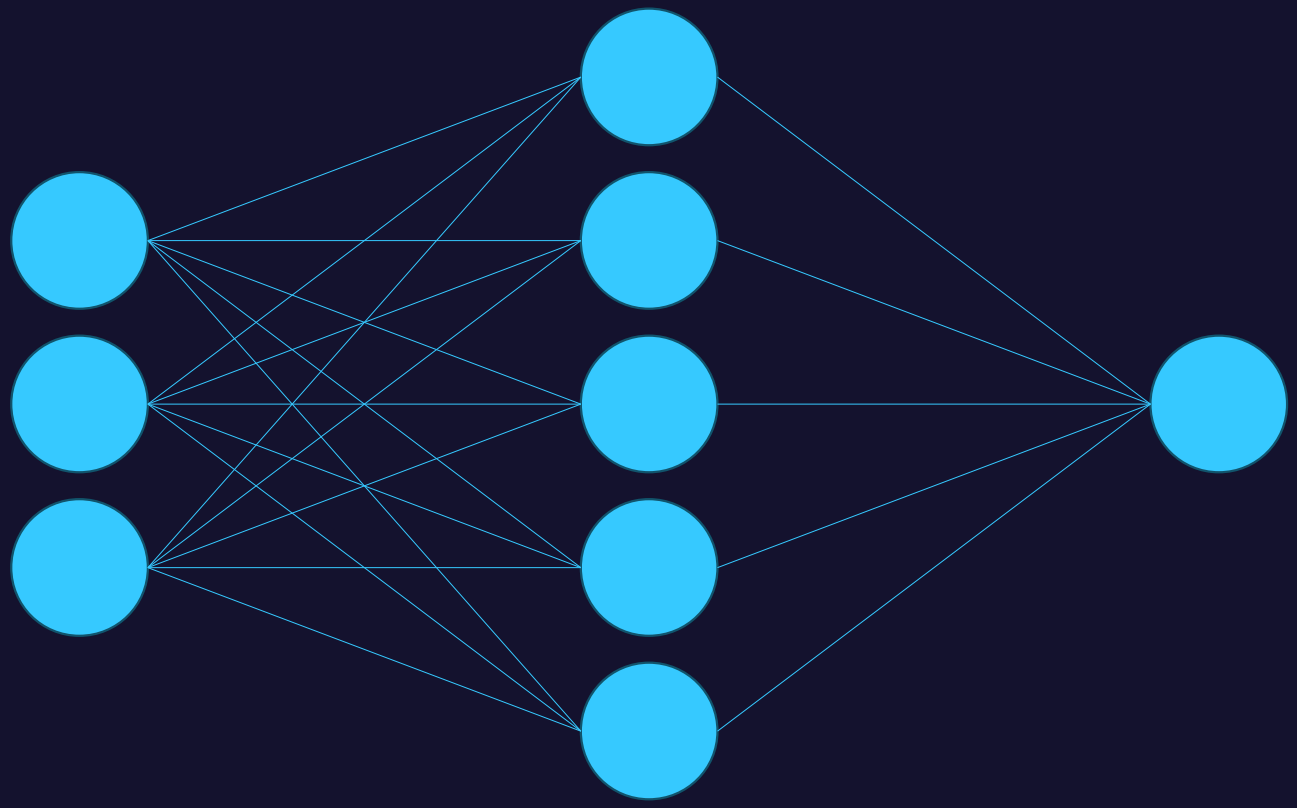
Hidden layer

Output layer

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

What is a Neural Network?

Machine Intelligence



Input layer

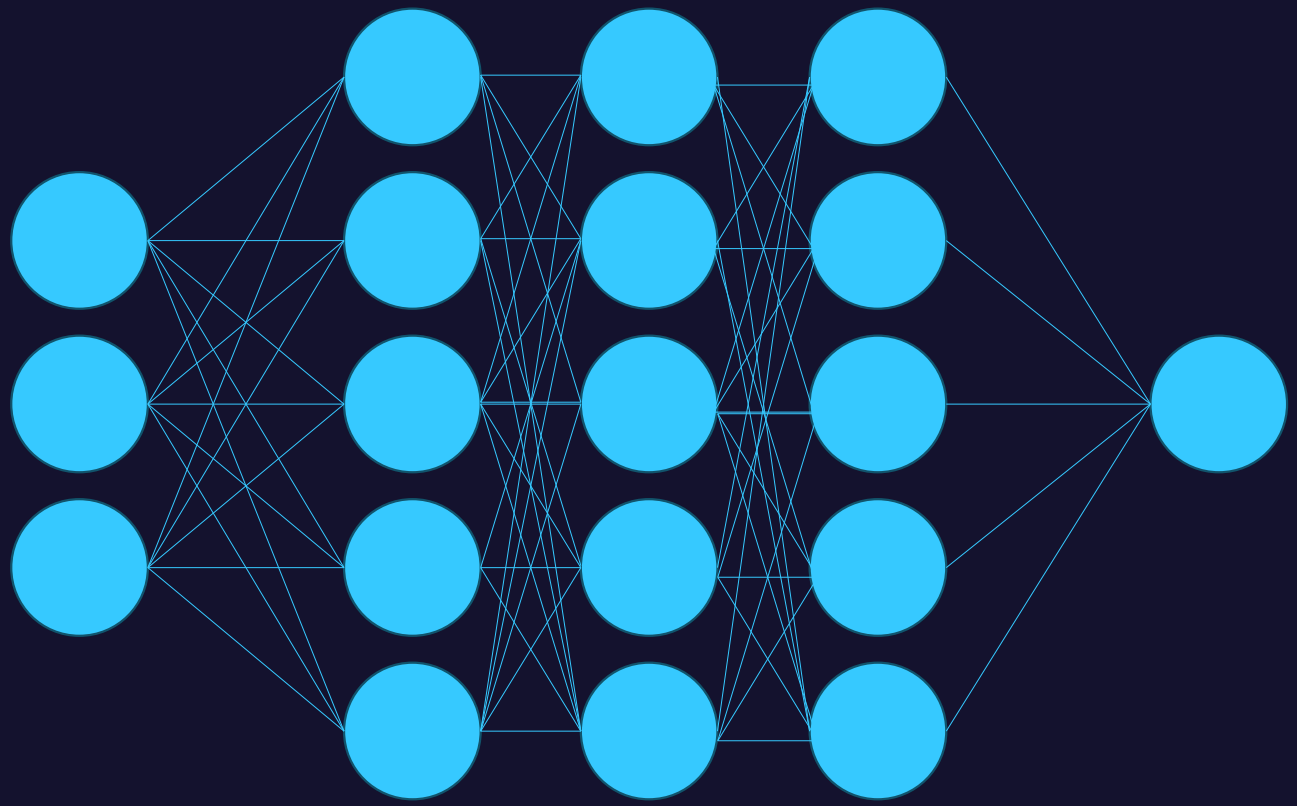
Hidden layer

Output layer

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

What is a Deep Neural Network?

Machine Intelligence



Input layer

Hidden layer

Output layer

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Pros and cons of NNs

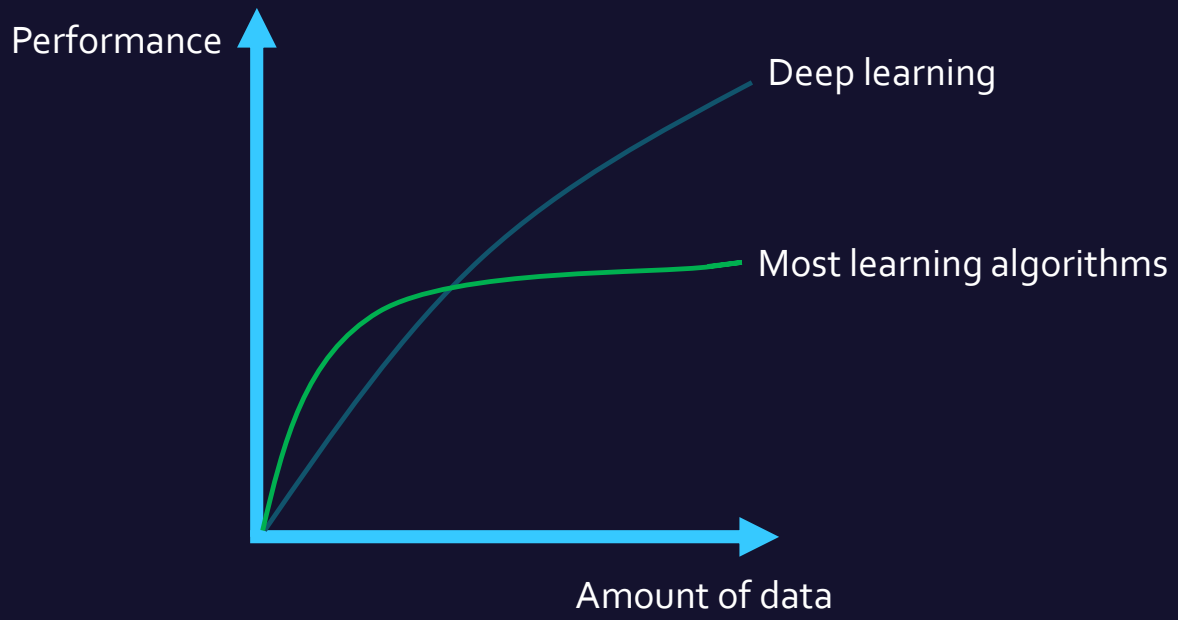
Machine Intelligence

- Pros:
  - Well understood methods for training
  - Massive user base
  - Provable that they can solve any task
  - Scalable

- Cons
  - Black boxes
    - Hard to know how they work
  - Hard to add domain knowledge efficiently
    - Also can be hard to work with odd data-types
  - Hardware inefficient
  - Typically need large amounts of training data

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

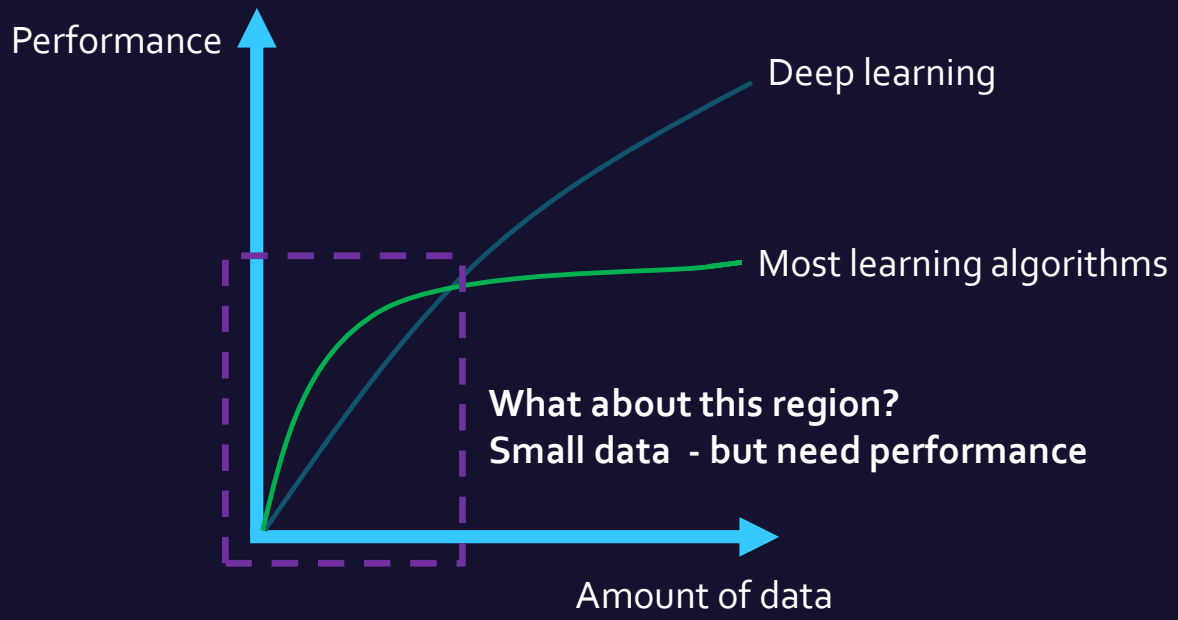
Pros and cons of NNs



(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Sarker, I.H. Deep Learning: A Comprehensive Overview on Techniques, Taxonomy, Applications and Research Directions. *SN COMPUT. SCI.* **2**, 420 (2021).

Pros and cons of NNs



(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Sarker, I.H. Deep Learning: A Comprehensive Overview on Techniques, Taxonomy, Applications and Research Directions. *SN COMPUT. SCI.* **2**, 420 (2021).

Pros and cons of NNs

Machine Intelligence

- Black box
  - What can we, as a human, do with the weight matrix?

- Validation
  - Models are often only as good as the training data
  - They can often only be validated as well as the testing data permits
  - How do we check for issues?
    - Overfitting
    - Underfitting
    - Bias

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Other types of ML

Machine Intelligence

- Regression
- Principle Component Analysis (PCA)
- K-Nearest Neighbour (KNN)
- Support Vector Machines (SVM)
- Bayesian Inference
- Decision trees / forests
- Evolutionary algorithms
- Many, many others…

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Other types of ML

Machine Intelligence

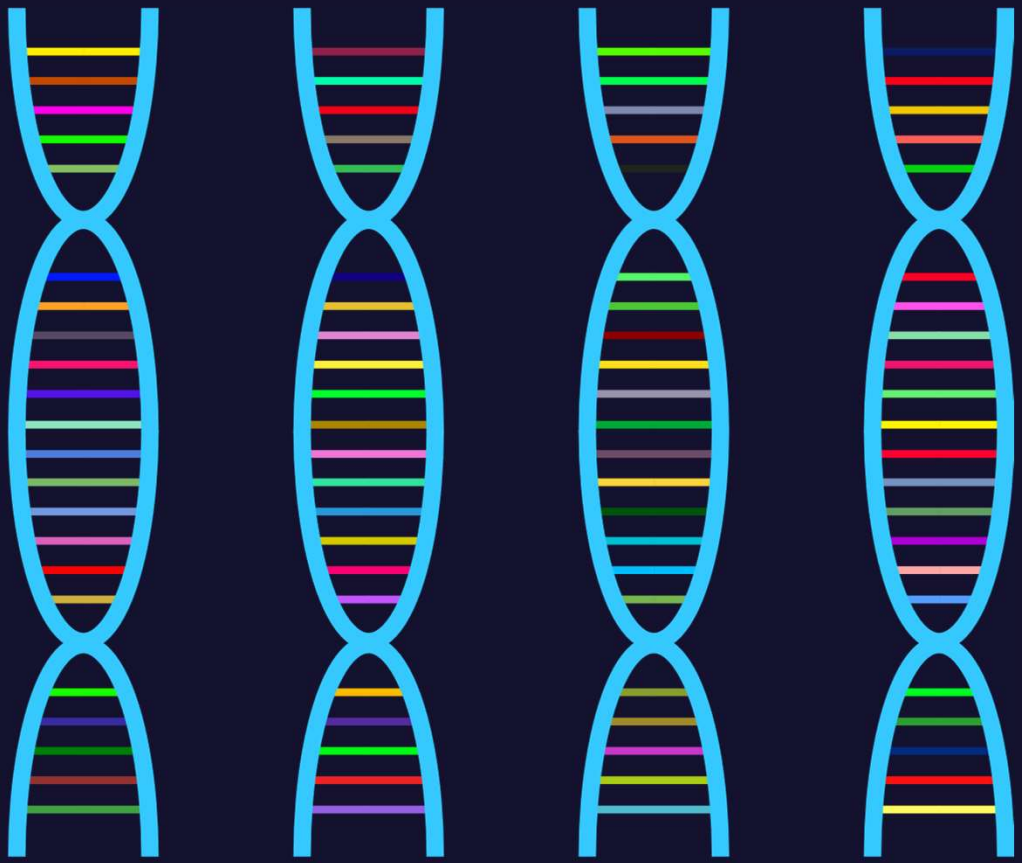
- Pros:
  - Lots of choice
    - Different models for classification, regression, detection etc.
  - Many have explanatory power
  - Some are unsupervised learners
  - Predictable behaviour

- Cons:
  - Not all are suitable for all data types
  - Not all scale well
    - In complexity
    - Number of inputs

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Our Technology

Machine Intelligence

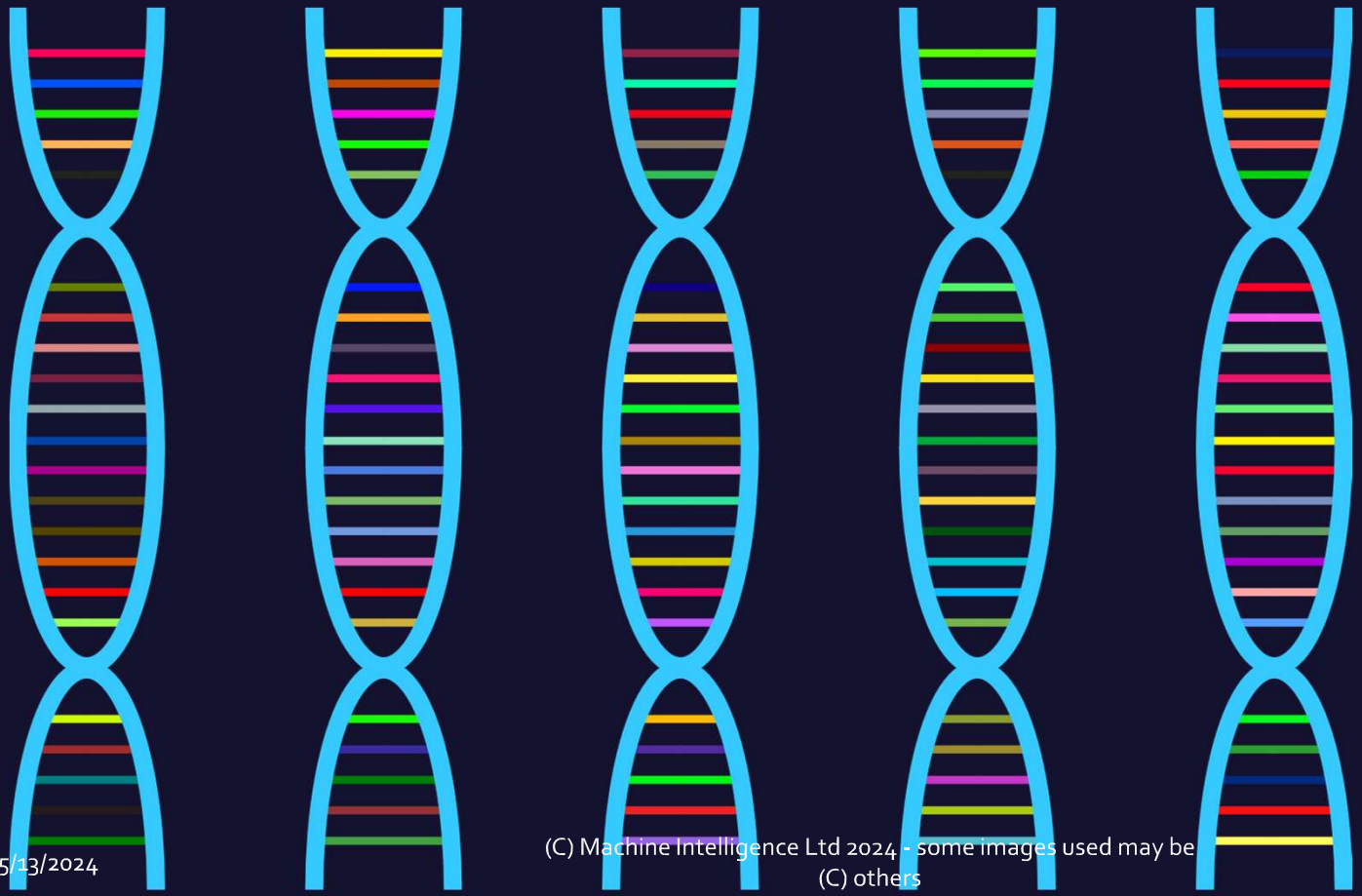


- Bio-inspired
- Genetic programming
  - Outputs computer programs
  - Application agnostic
  - Easy to add domain knowledge
  - Scalable

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Evolutionary Algorithms

Machine Intelligence

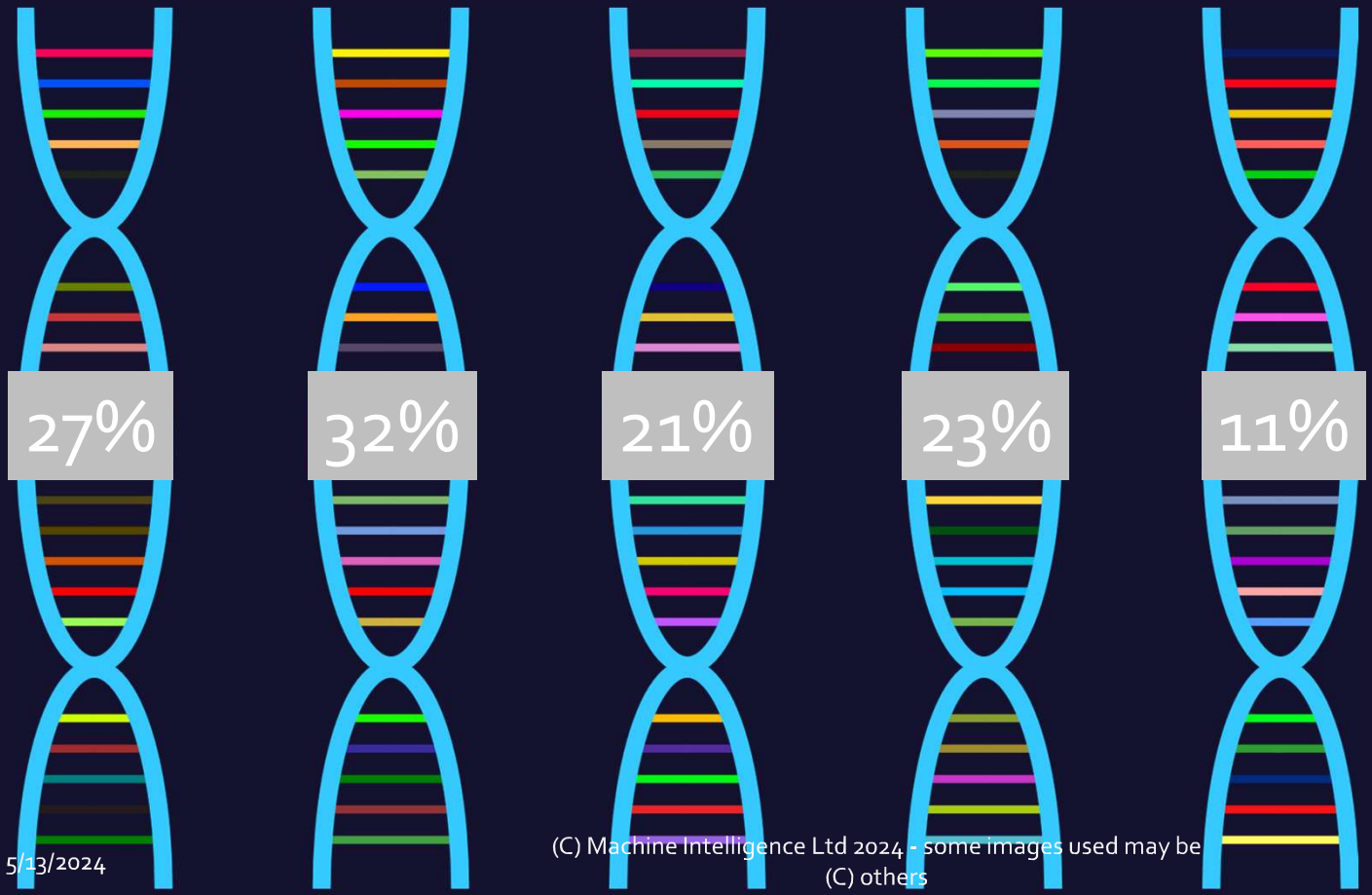


Random Generated Population

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Evolutionary Algorithms

Machine Intelligence

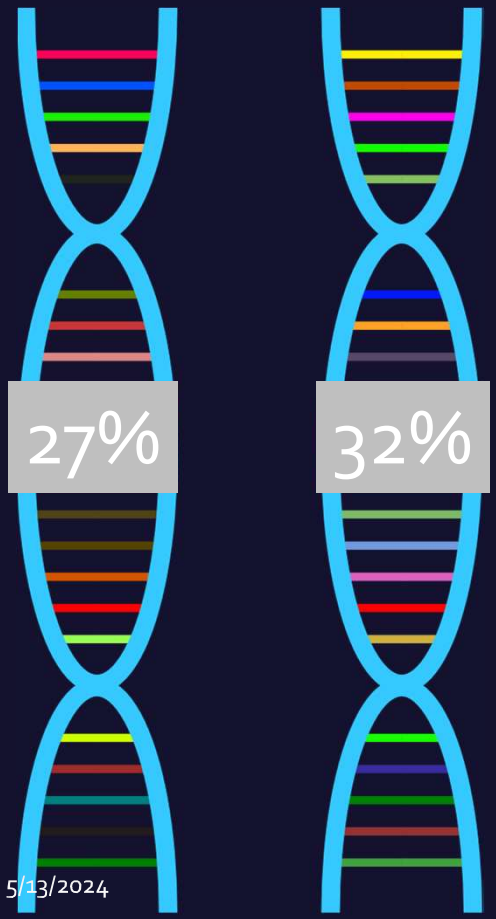


Fitness Evaluation

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Evolutionary Algorithms

Machine Intelligence

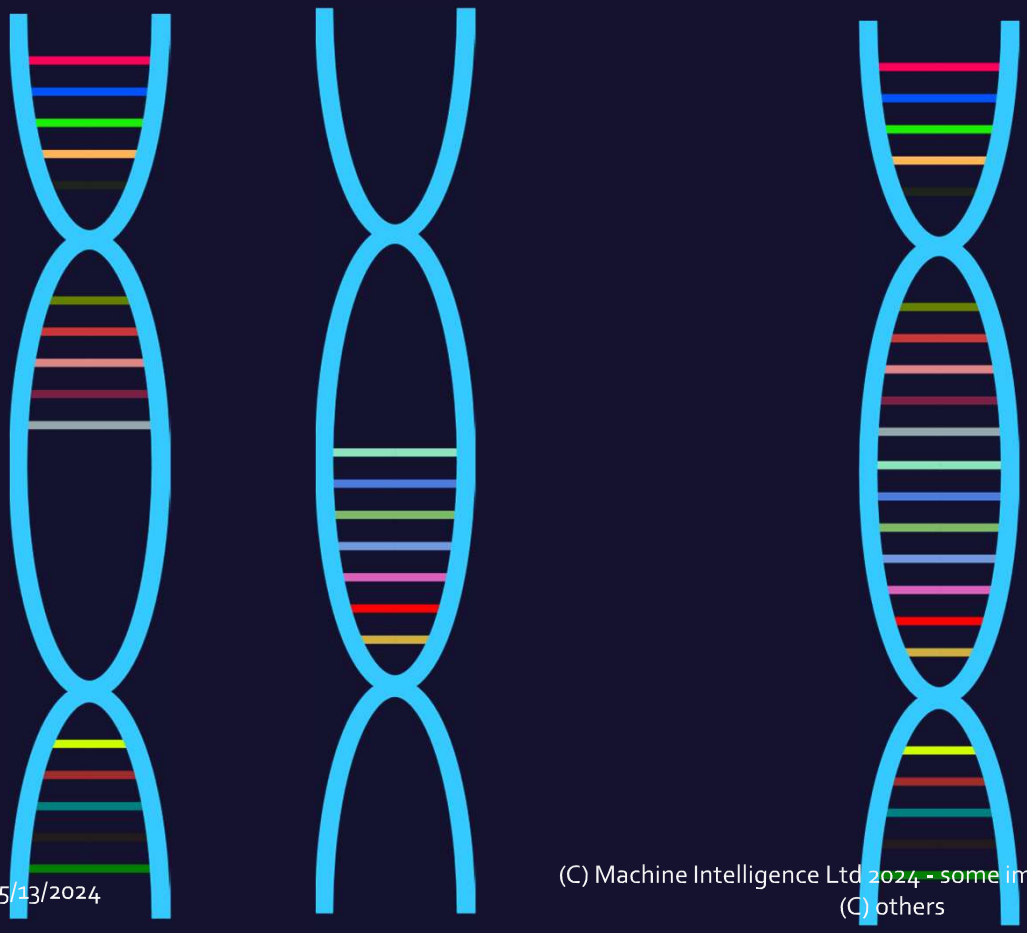


Build next population: Select Parents

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Evolutionary Algorithms

Machine Intelligence

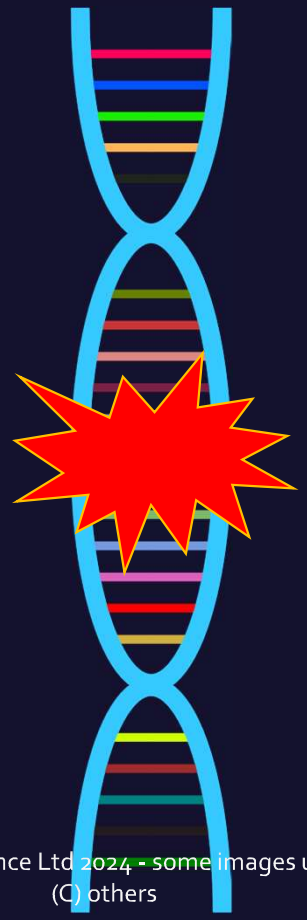


Build next population: Generate child by crossover

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Evolutionary Algorithms

Machine Intelligence

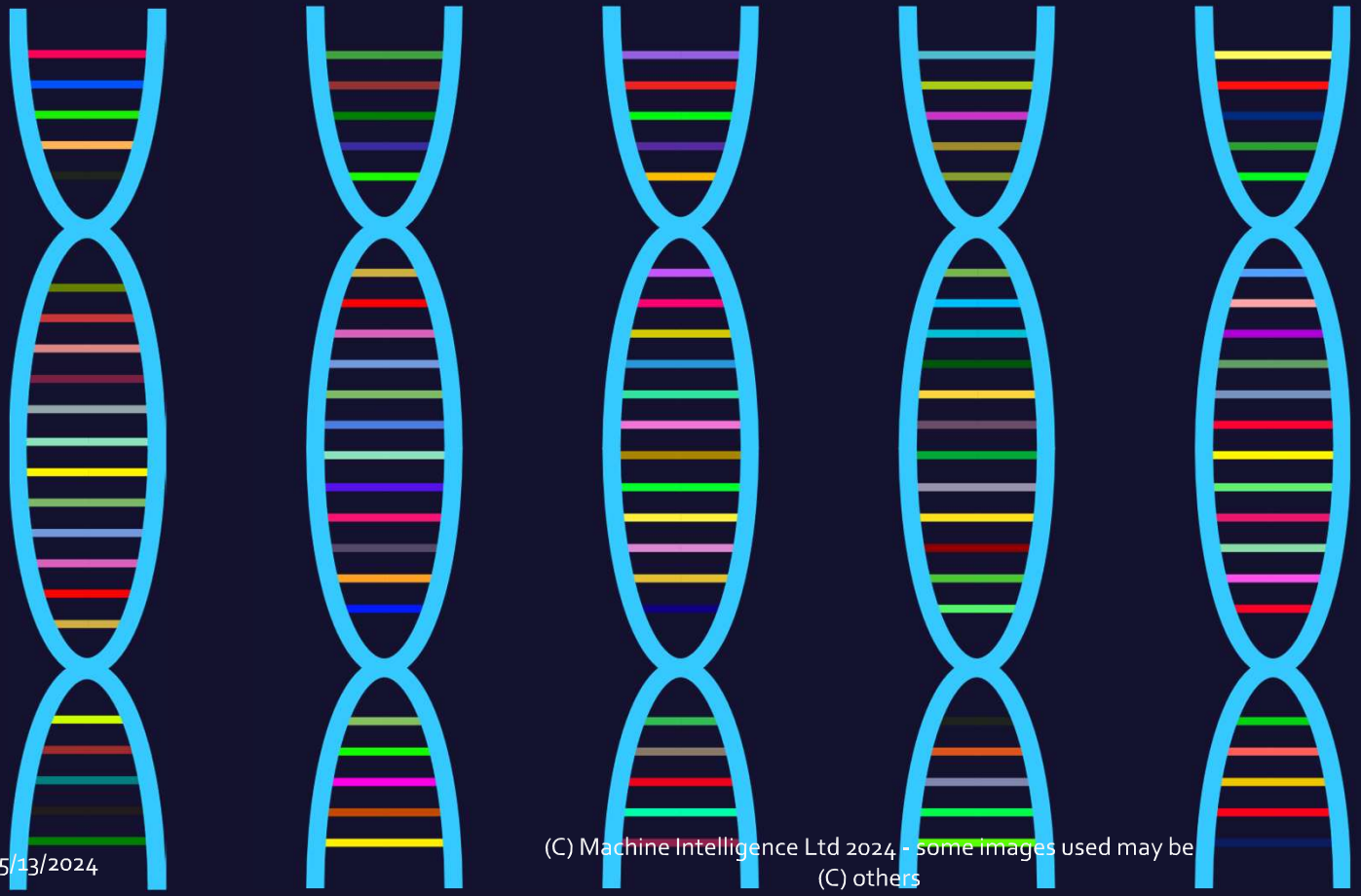


Build next population: Mutation

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Evolutionary Algorithms

Machine Intelligence

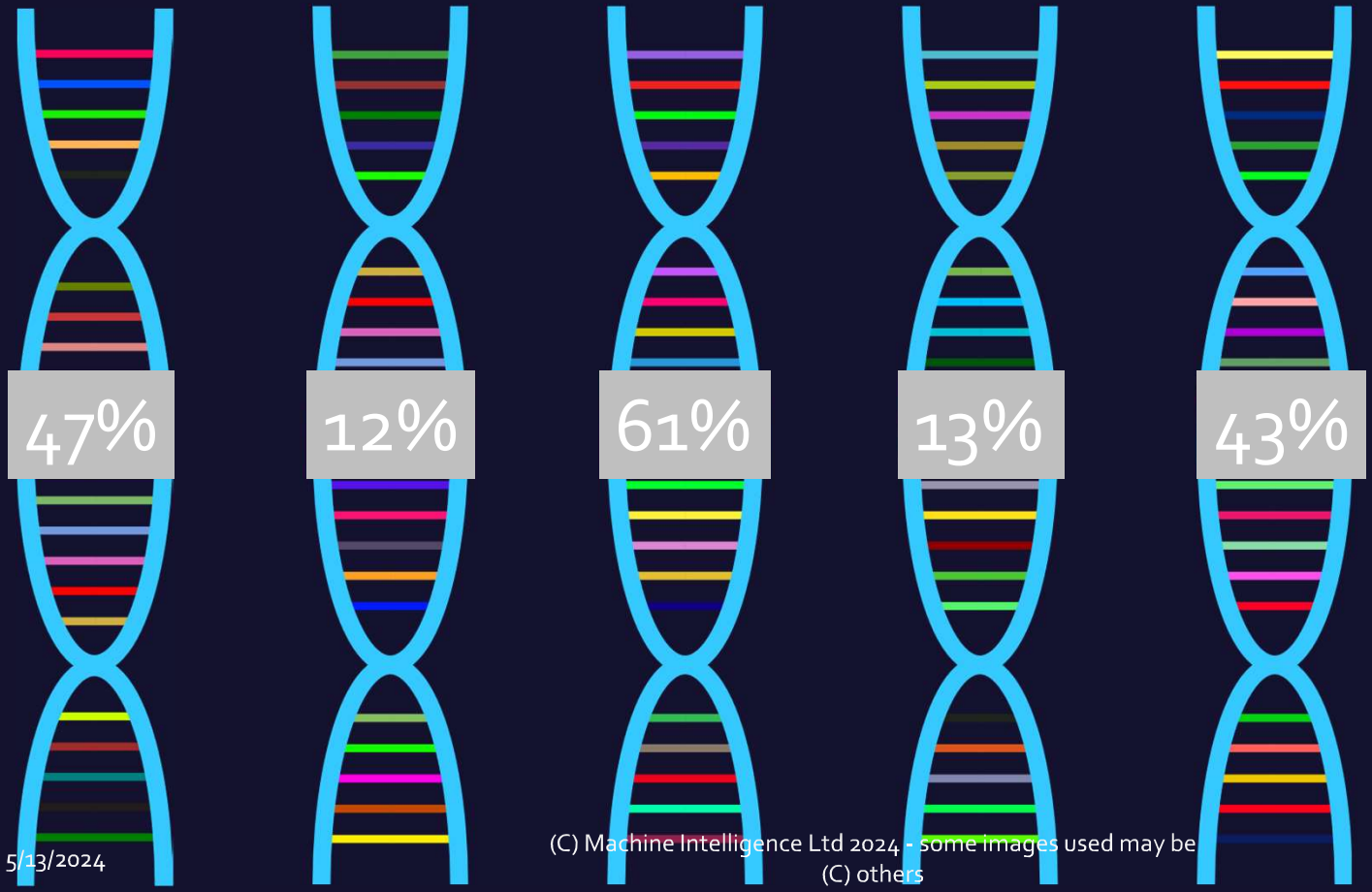


Build next population: Repeat until new population complete

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Evolutionary Algorithms

Machine Intelligence

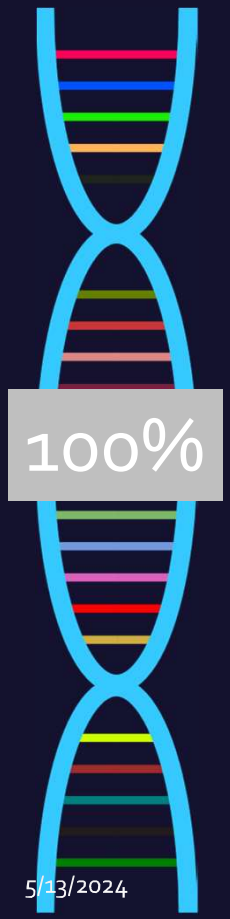


Test
New
Population

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Evolutionary Algorithms

Machine Intelligence

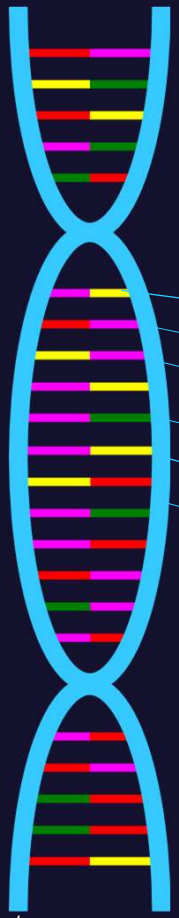


Repeat until success

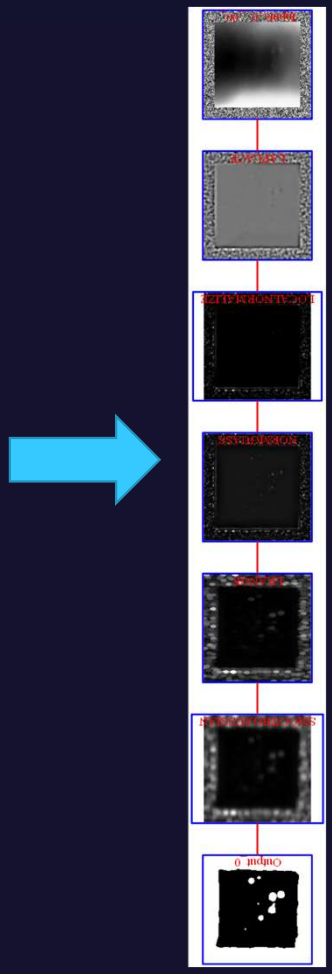
(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Our technology

Machine Intelligence



```
Node1 = Laplace(Inputs[0], 13)
Node2 = LocalNormalize(Node1, 12, 1)
Node3 = LocalNormalizeWithGauss(Node2, 6, 7)
Node4 = LocalStats(Node3, 8, 5, Range)
Node5 = SmoothGaussian(Node4, 1, 18)
Output = Threshold(Node5,12.3)
```



Digital DNA

Represents computer programs

Allows for introspection

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Technology

Machine Intelligence

There are 5 software levels to consider:

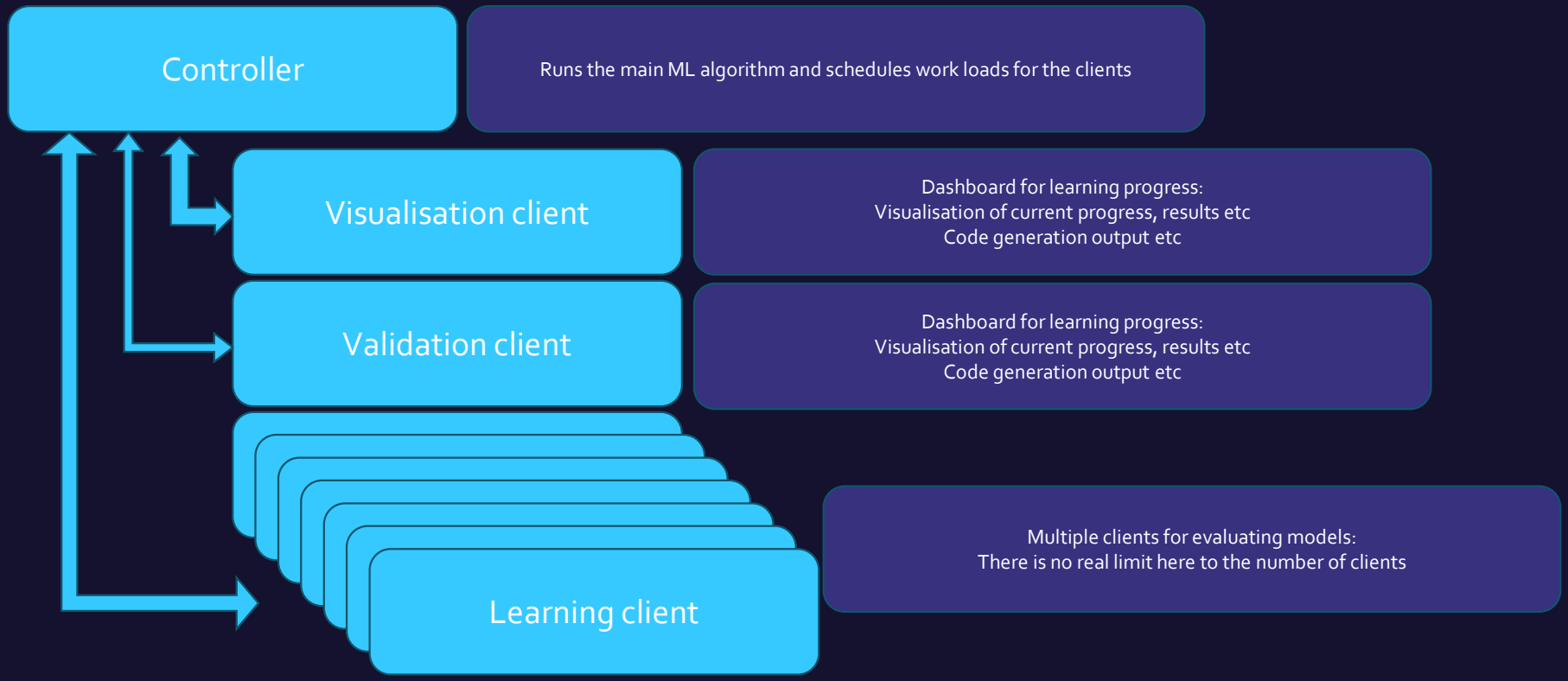
Labelling software	Tools for letting the user view images in a conventional way and mark up areas of interest
Image processing library	Software library providing algorithms for image manipulation. MI library is combination of OpenCV and custom/closed source algorithms. End user may want to extend this.
Machine learning	The evolutionary algorithm, distributed learning and visualisation tools for the ML.
Run time	Three ways to use the generated models: 1) Via API 2) Use generated code + image processing library 3) Command line application
Top-end application	End user application. Most likely 3rd party software

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Technology

Machine Intelligence

Overview of ML architecture:



(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Technology

Machine Intelligence

Current development status:

Labelling software	Desktop application: C#, WPF, optimised for digitising tablet. Image processing for human operators and other actions targeted for digital X-ray.
Image processing library	.net library: Commercial OpenCV license
Machine learning	.net applications: C# 4.8, WCF for IPC
Run time	.net applications
Top-end application	Proof-of-concept complete for BAE. Also integrated into RR project.

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Technology

Machine Intelligence

Future development:
(With focus on Programmable collab)

Labelling software	Move to web application: Would need expertise outside of MI to develop
Image processing library	Update: MI to update this to latest versions of all platforms Check cross-platform and GPU support
Machine learning	Re-develop: MI would need to update this to use new infrastructure from Programable etc
Run time	Re-develop: 1) Programmable interface 2) Library API 3) Code generator export
Top-end application	Connect to Siemens apps etc

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Use case: X-ray inspection

Machine Intelligence

MADE SMARTER

Part of the minimum viable product phase cohort

TECHNOLOGY ACCELERATOR

BAE SYSTEMS

- Finalist for Digital Catapult's "Made Smarter Technology Accelerator"

  https://accelerator.madesmarter.uk/

- Developing AI based system for visual inspection of airplane components: x-ray weld assessment

- Working with BAE Systems in Samelsbury

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Use case: X-ray inspection

Machine Intelligence

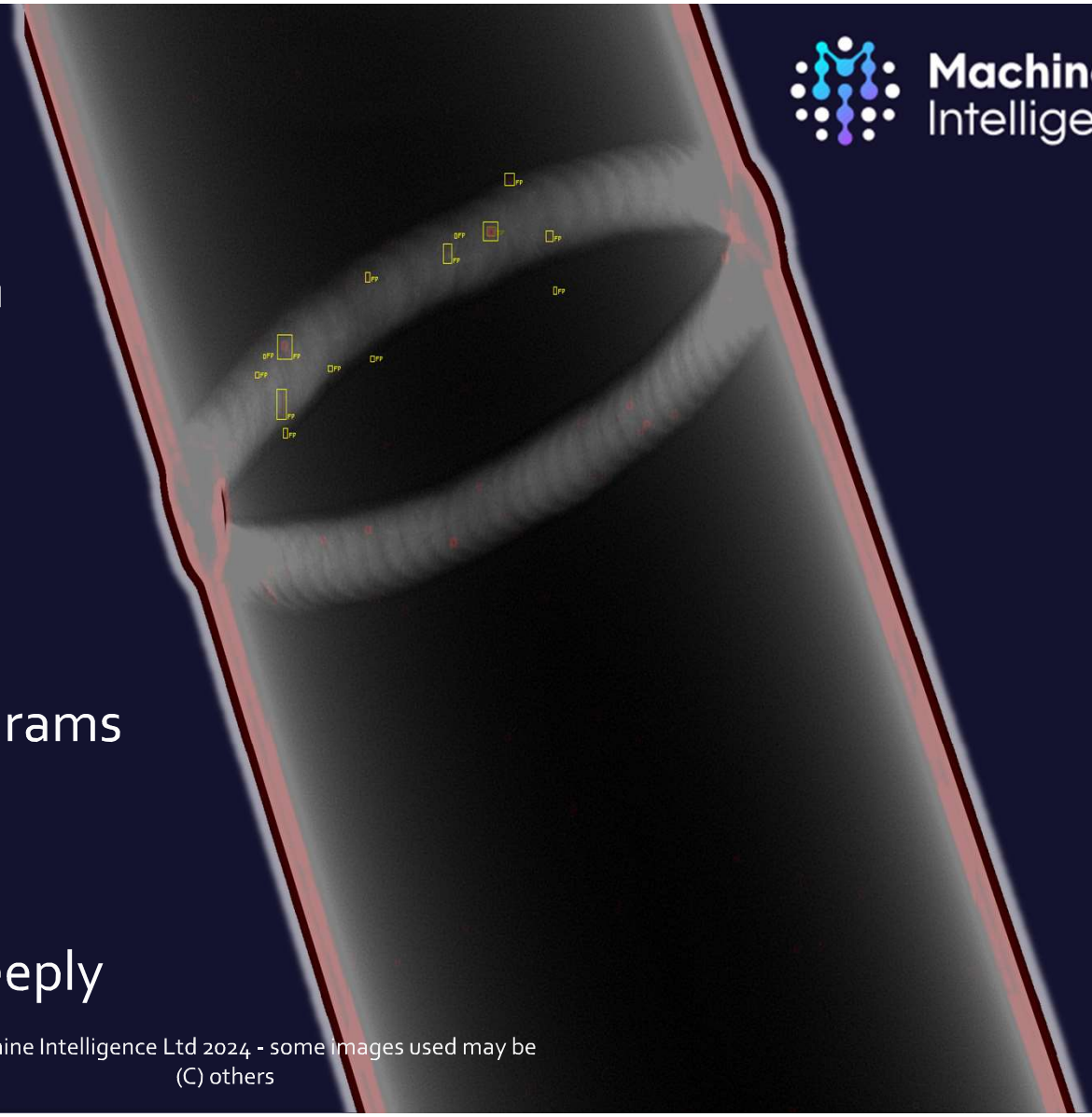
MVP target problem: Image Based Defect Detection

- Visual inspection of digital images
- Time consuming, laborious, skilled
- Critical importance for defence and aerospace
- Integrated decision making for the operator

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Our Solution

- Our machine learning system
  - ✓Unique technique
  - ✓**Small training set**
  - ✓Rapid set up time
  - ✓Generates computer programs
  - ✓**Understandable output**
- New software to integrate deeply with inspection process

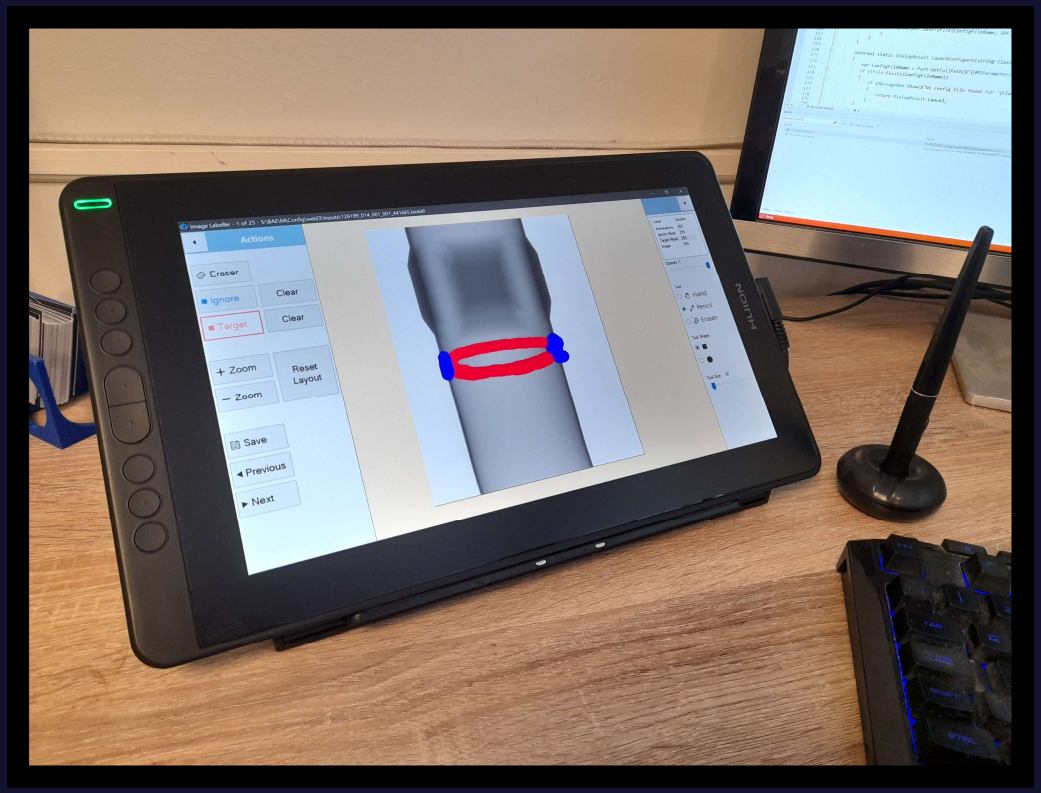


Machine Intelligence

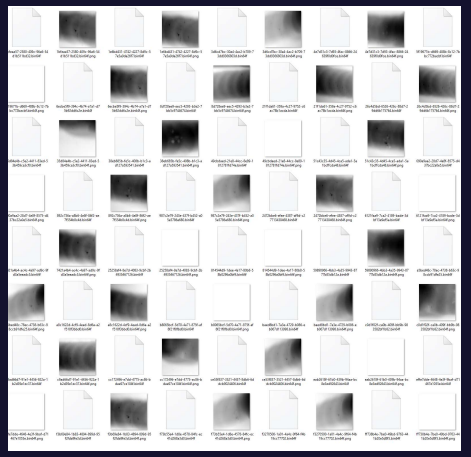
(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Making the training set

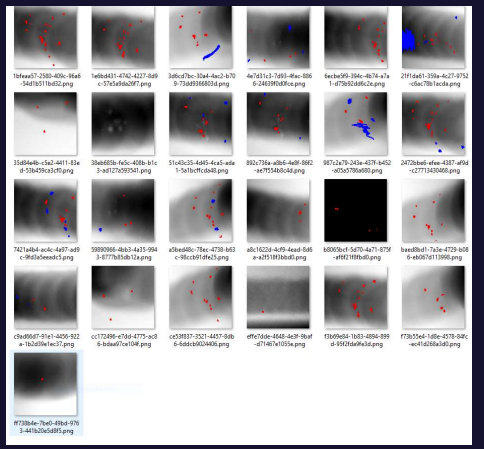
Machine Intelligence



Inputs:



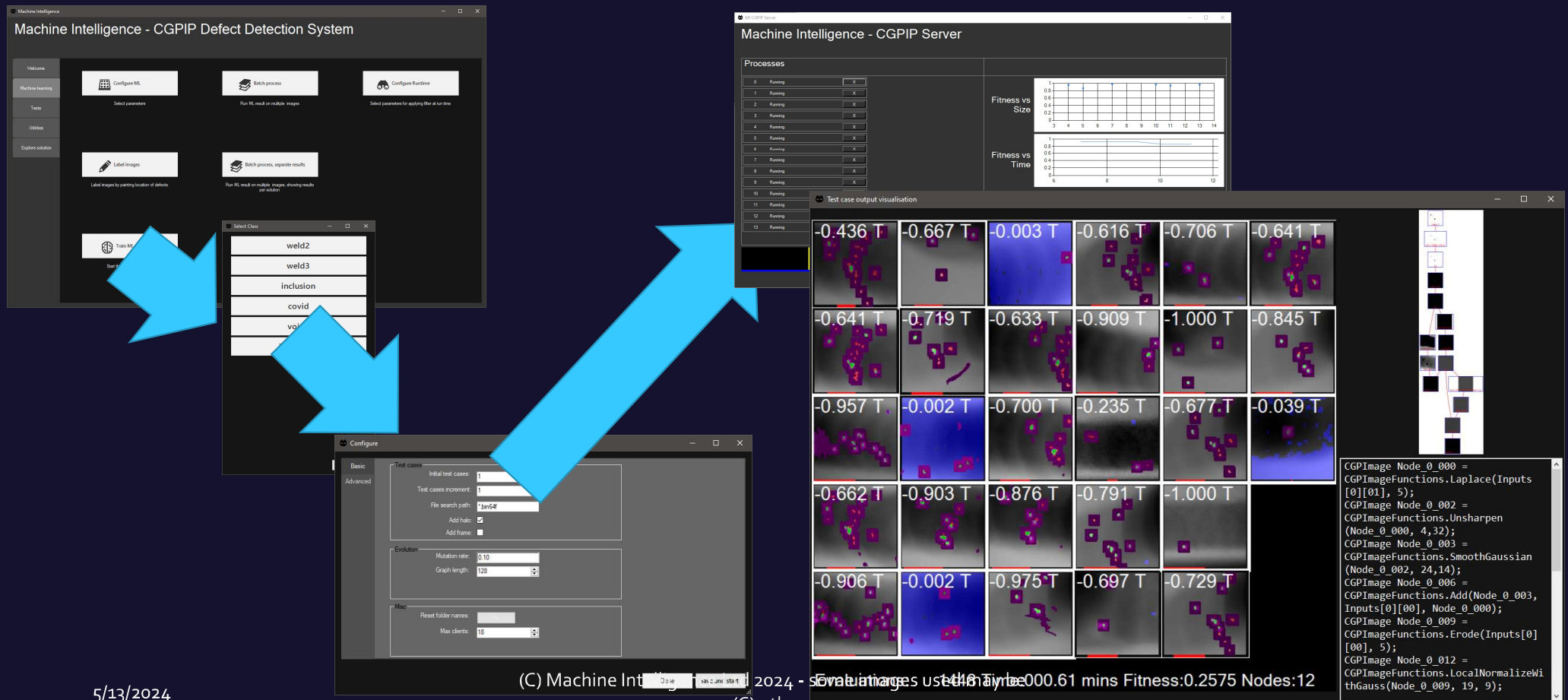
Targets:



(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

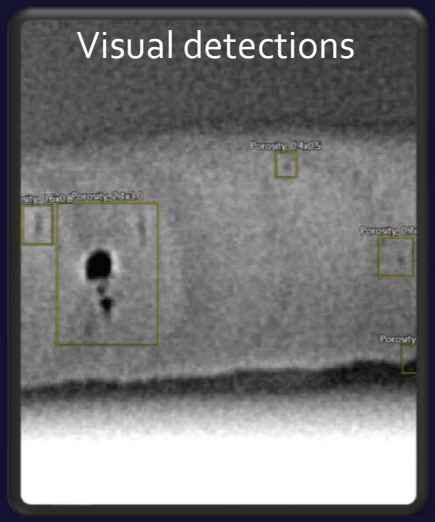
Machine Learning

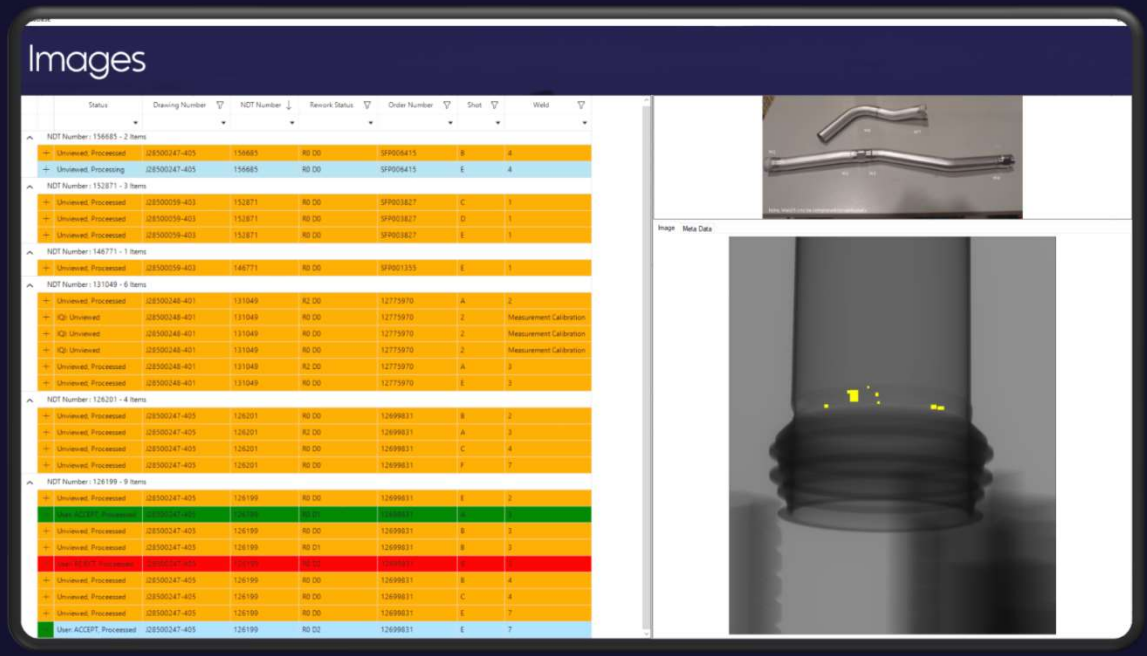
Machine Intelligence



(C) Machine Int 2024 - sl
(C) others

Machine Intelligence



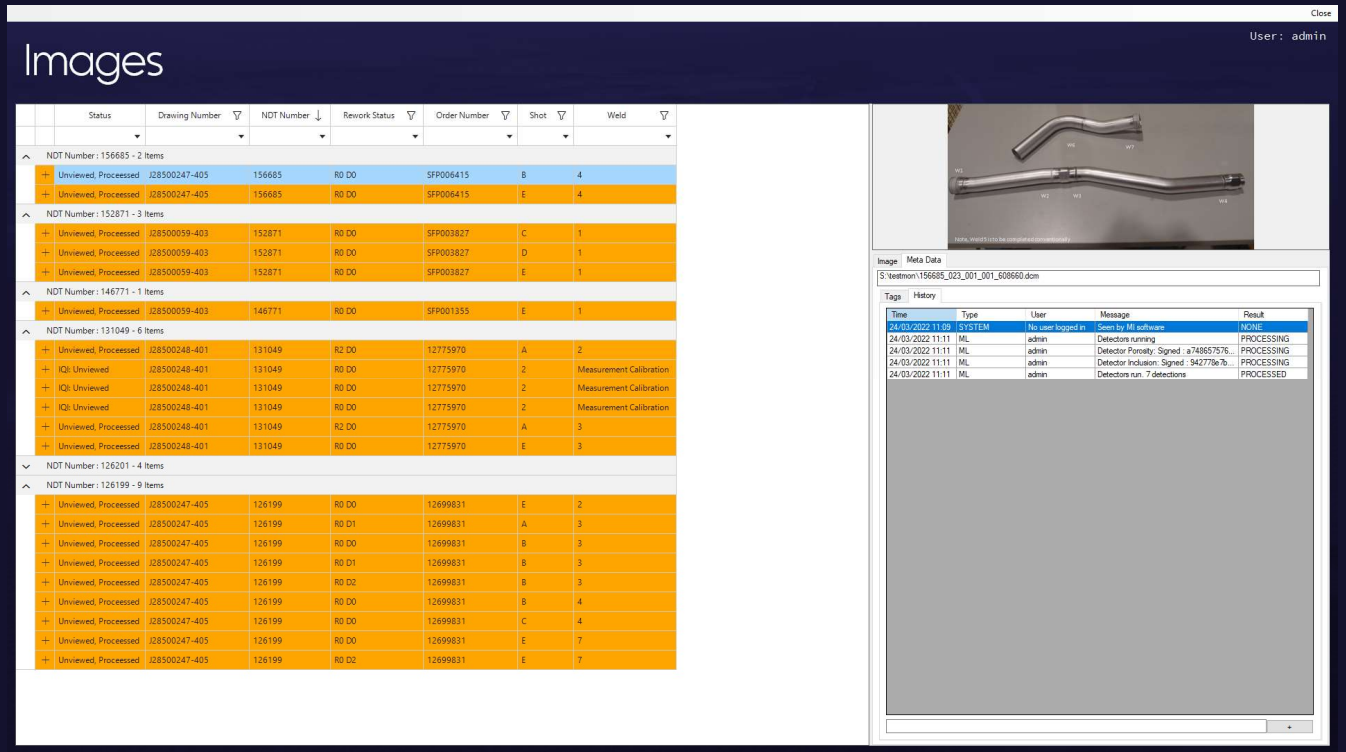


Visualise detection results on dashboard

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

X-ray Software for BAE

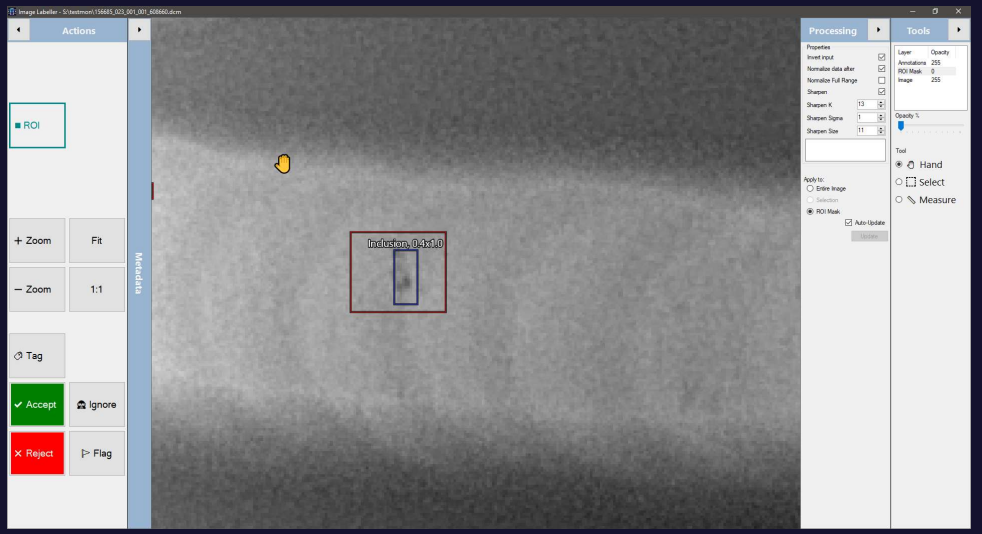
Machine Intelligence



(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

X-ray Software for BAE

Machine Intelligence



User can explore images with viewing software and make final Pass/Fail decisions

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Use case:Visual defects for RR

Machine Intelligence

- Defect Detection and Measurement System
- AI powered defect detector
- Multi-modal measurement + sentencing of components
- Full automation
- 1 system deployed and used in production
- 1 system nearing completion

Automated inspection system :
3D scanning, metrology and vision

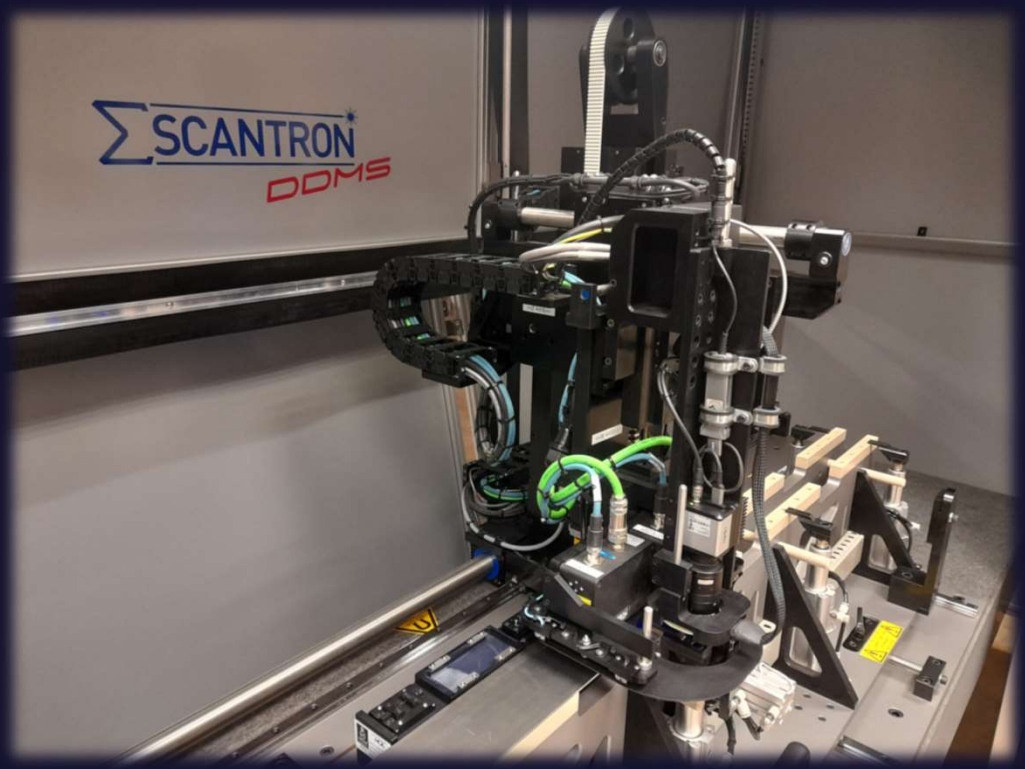
ROLLS ROYCE

SCANTRON

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Use case:Visual defects for RR

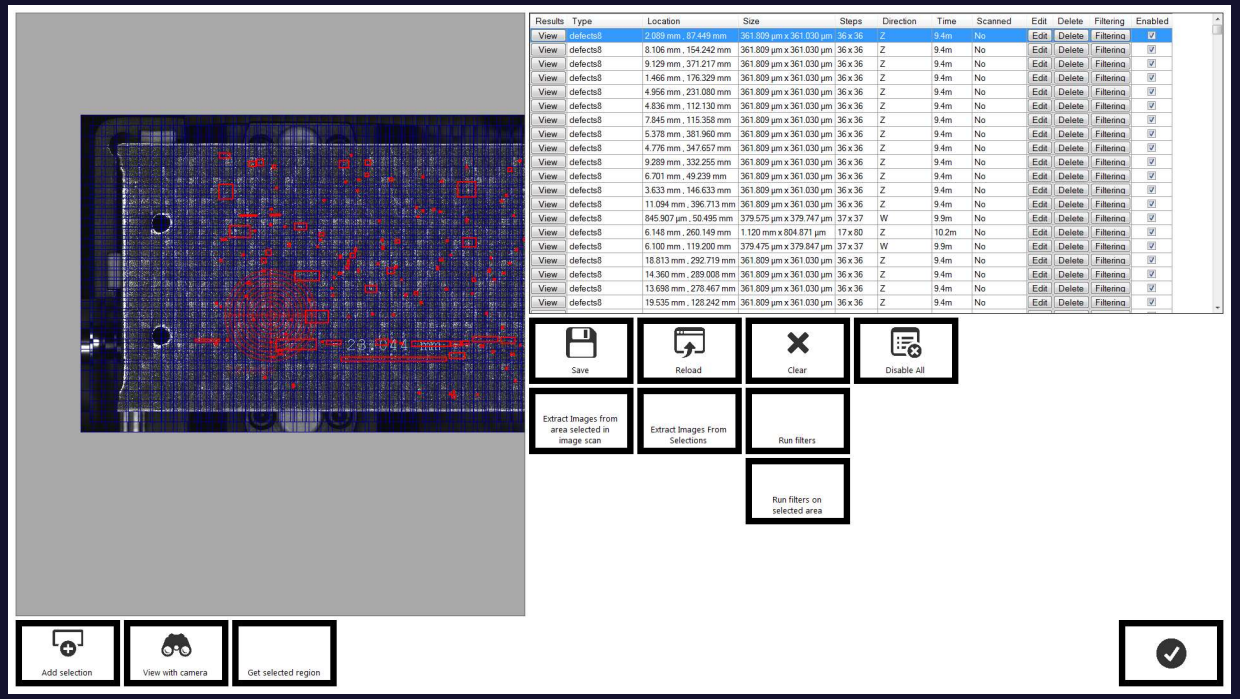
Machine Intelligence

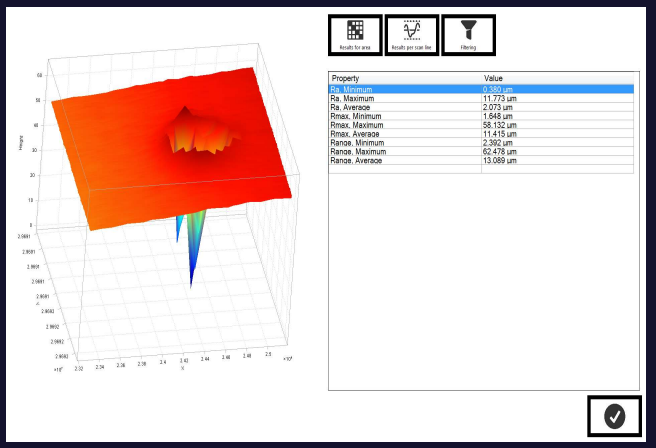


(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Use case: Visual defects

Machine Intelligence





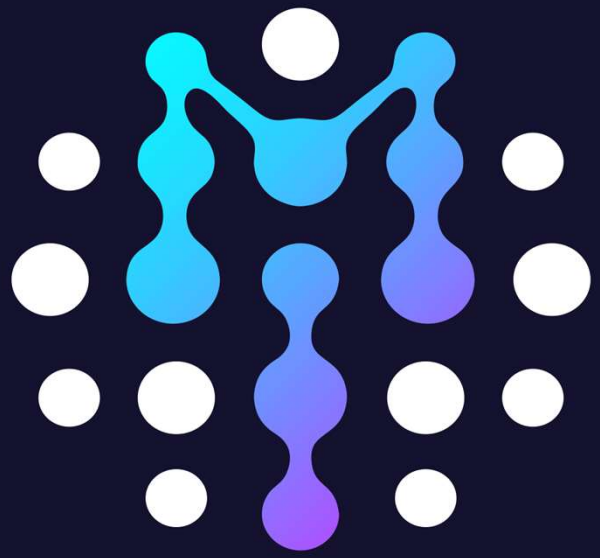
(C) Machine Intelligence Ltd 2024 - some images used may be (C) others

Final thoughts

Machine Intelligence

- AI extremely important and useful in NDT
- Many different types of ML out there to use
  - Pros and cons for each
- Selecting the right ML algorithm may be important for your application
  - Meet regulatory issues
  - Be confident in the solution
  - Learn something about your problem

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others



www.**Machine**Intelligence.co.uk

simon@machineintelligence.co.uk

Thank you for listening – any questions?

(C) Machine Intelligence Ltd 2014 - some images used may be (C) others

(C) Machine Intelligence Ltd 2024 - some images used may be (C) others