Session 1: Introduction to AI in Semiconductor Applications

BITS Pilani Dubai Campus
25 YEARS OF EXCELLENCE

60
PIONEERING EDUCATION PARADIGMS

VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Value Added Program (Hybrid)

VAC2514 Artificial Intelligence in Semiconductor Industry Applications

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Chair, ACM-W Professional Chapter –Dubai
Vice Chair, ACM Professional Chapter –Dubai
Stanford-Elsevier Top 2% World Scientists (2024)

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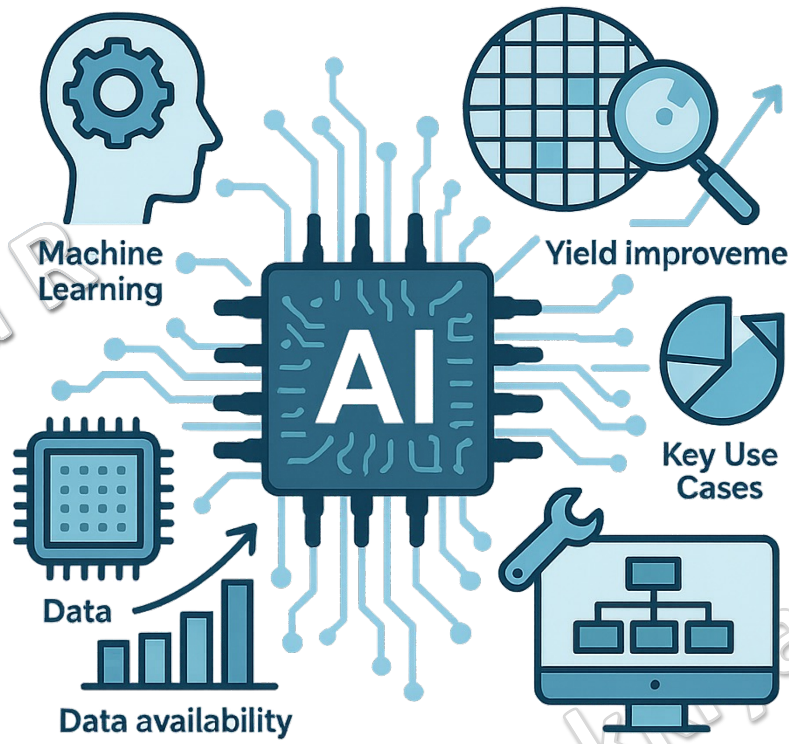
Expertise

- Artificial Intelligence, Deep Learning, Cognitive and Affective Computing and Multimodal Data Fusion
- Led 16 Projects (SERB, DST, DRDO-iDEX, Royal Society UK, AICTE, Trjaectorie, TVS Credits, TVS Motors, etc.)
- Authored 75+ papers, 6 patents, 6 books and 7 chapters

Profile: | | iD | Scopus | | in

Overview

- AI for Next-Gen Semiconductor Workflows
- Quick refresher: AI, ML, and DL fundamentals
- Key use-cases across design and manufacturing
- Overview of real AI tools (Cadence, Synopsys, Intel)
- Challenges in real-world AI adoption
- Summary



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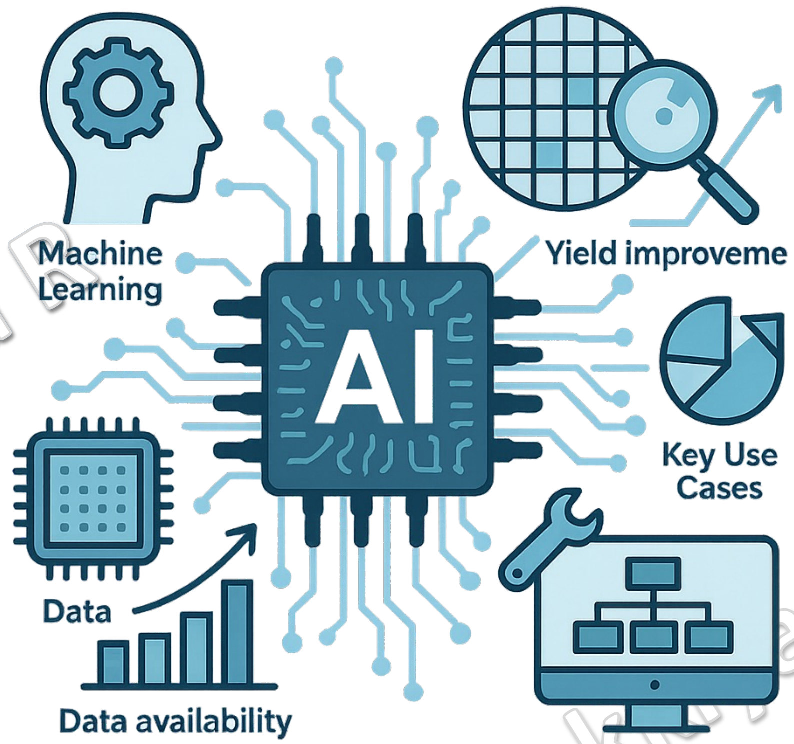


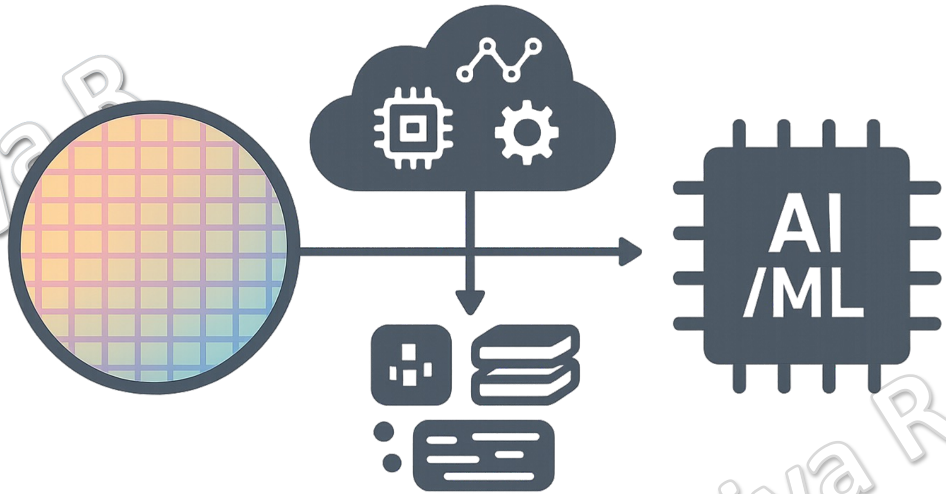
Artificial Intelligence

- Artificial Intelligence is
  - on everyone's lips right now
  - fastest growing branch of the high-tech industry
- Aims at enabling machines to perform tasks intelligently
- Often used with machine learning, big data, or deep learning

AI **learns from experience and makes new decisions independently**

AI in Semiconductor Industry

- **Modern semiconductors are incredibly complex** → Billions of transistors, nanoscale precision, tight yield margins
- **Manufacturing involves hundreds of interdependent steps** → Each stage (design, lithography, inspection, test) generates massive data
- **Manual tuning, inspection, and control are no longer scalable**
- **AI brings automation, prediction, and optimization** → Faster decision-making, adaptive control, defect prediction, real-time feedback
- **AI enables fabs to move from reactive to predictive** → Result: higher yield, reduced costs, improved throughput



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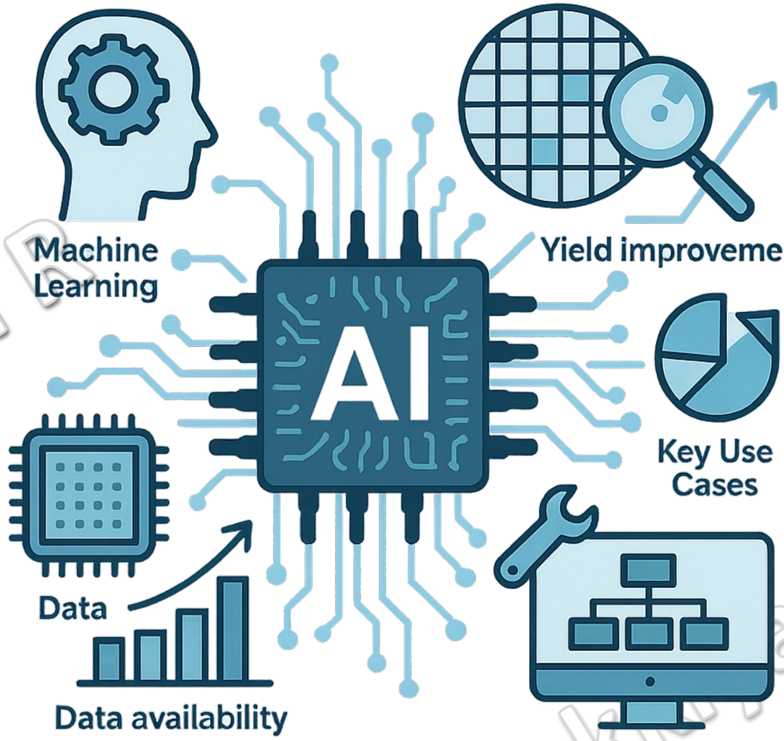
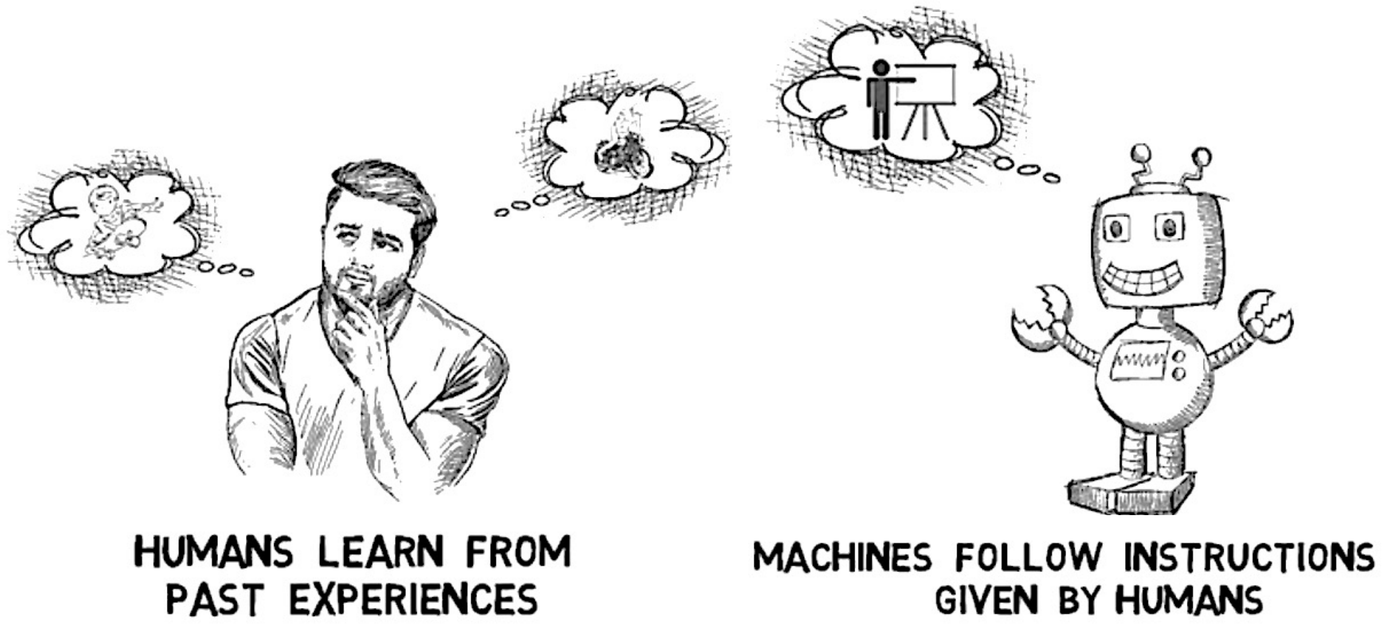


MACHINE LEARNING

Machine Learning is……

HUMANS LEARN FROM PAST EXPERIENCES

Machine Learning is…..



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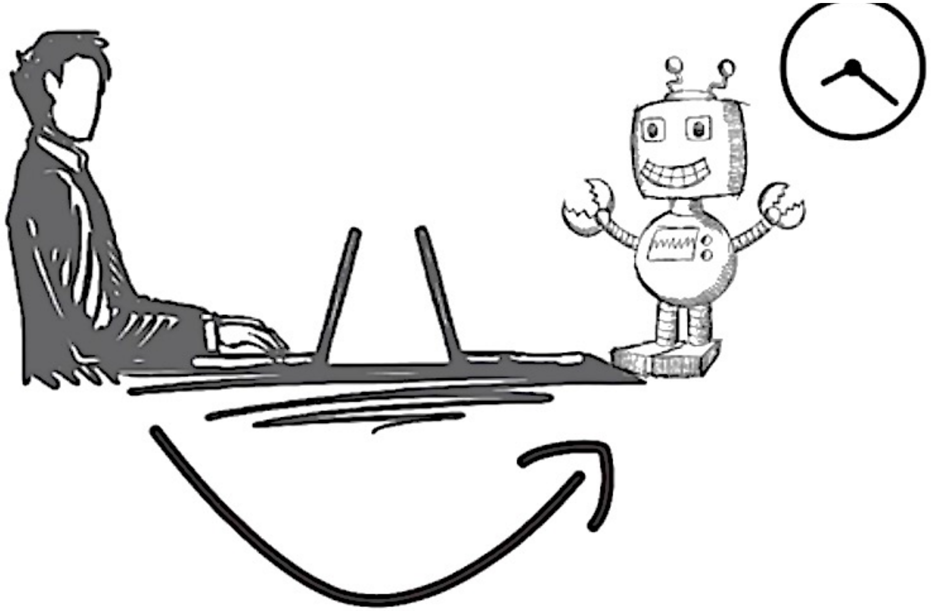
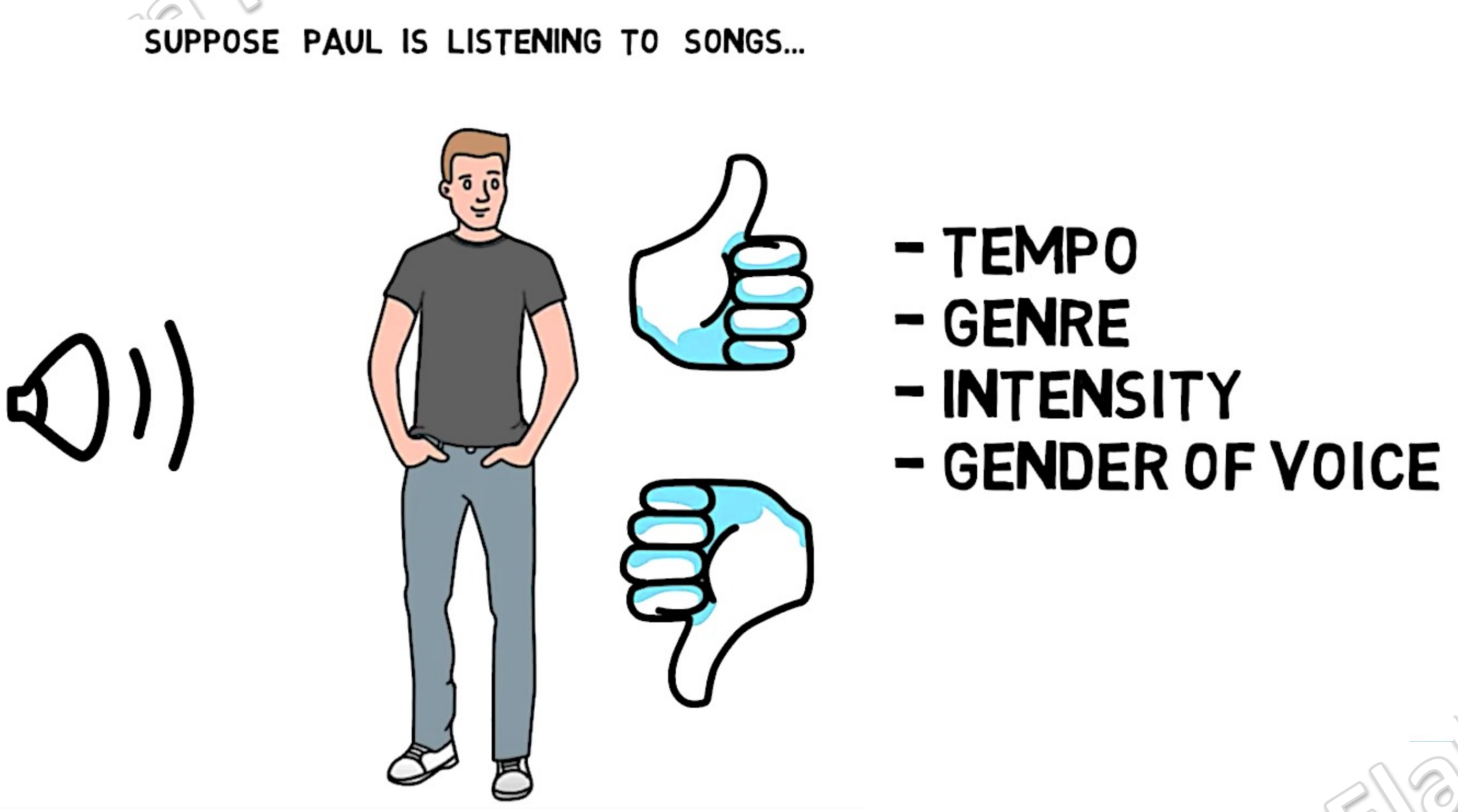


WHAT IF HUMANS CAN TRAIN THE MACHINES...

Machine Learning is……



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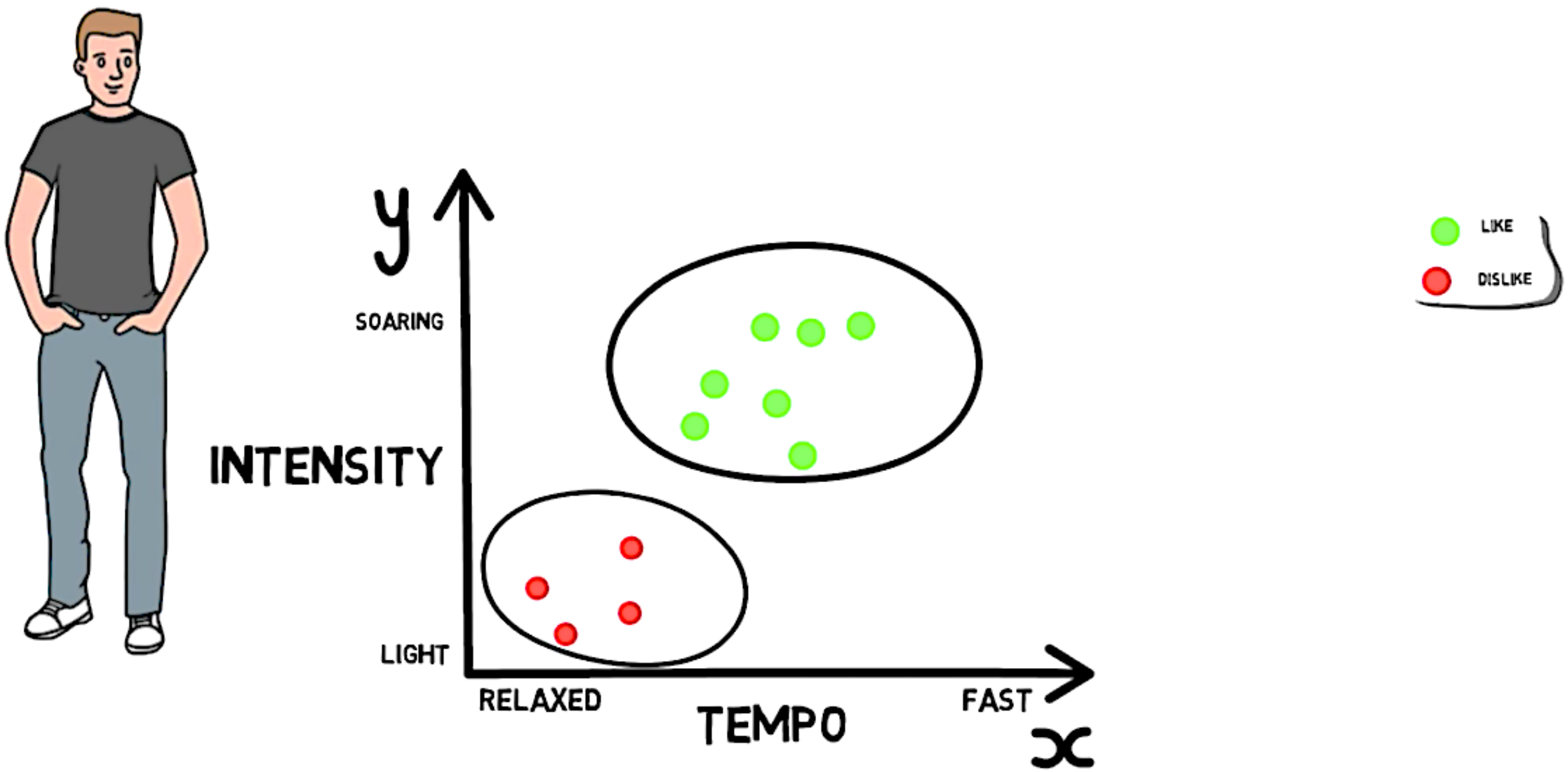

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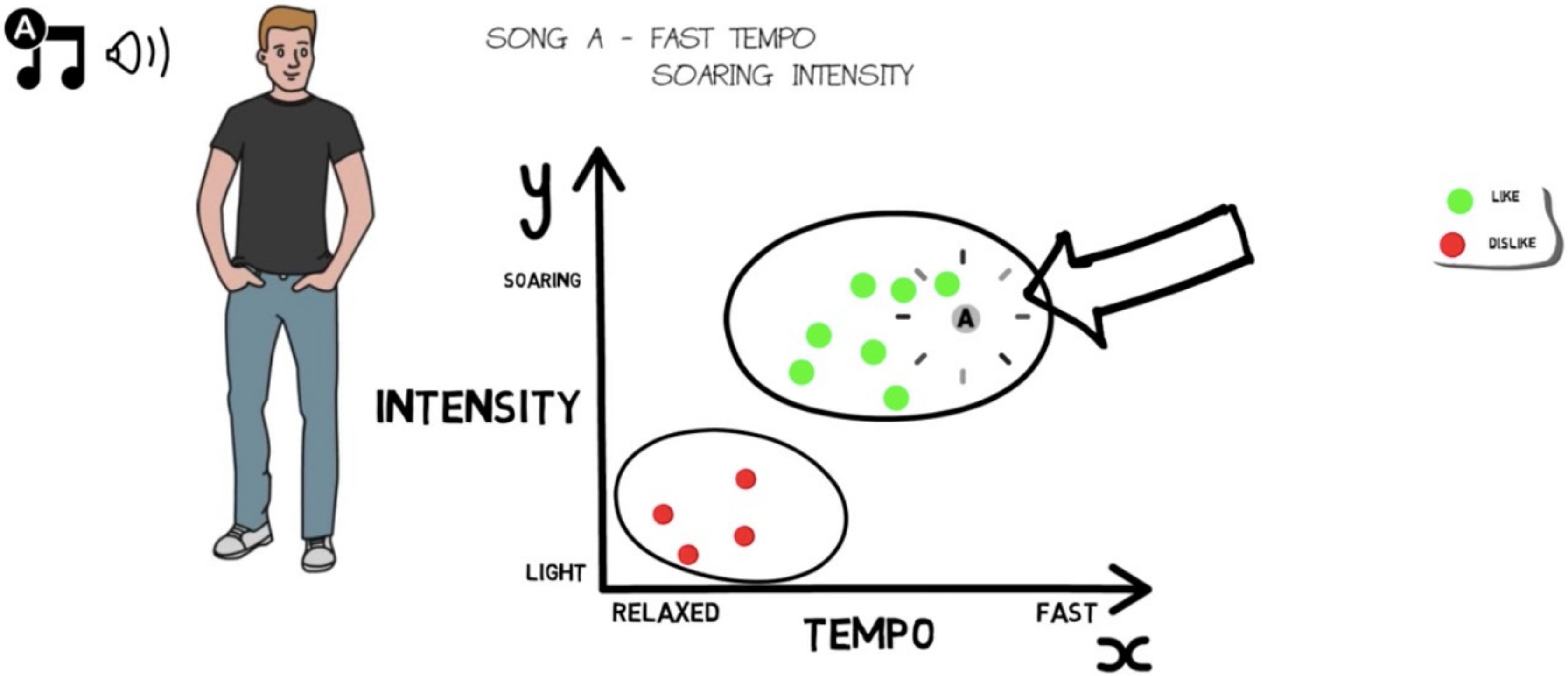

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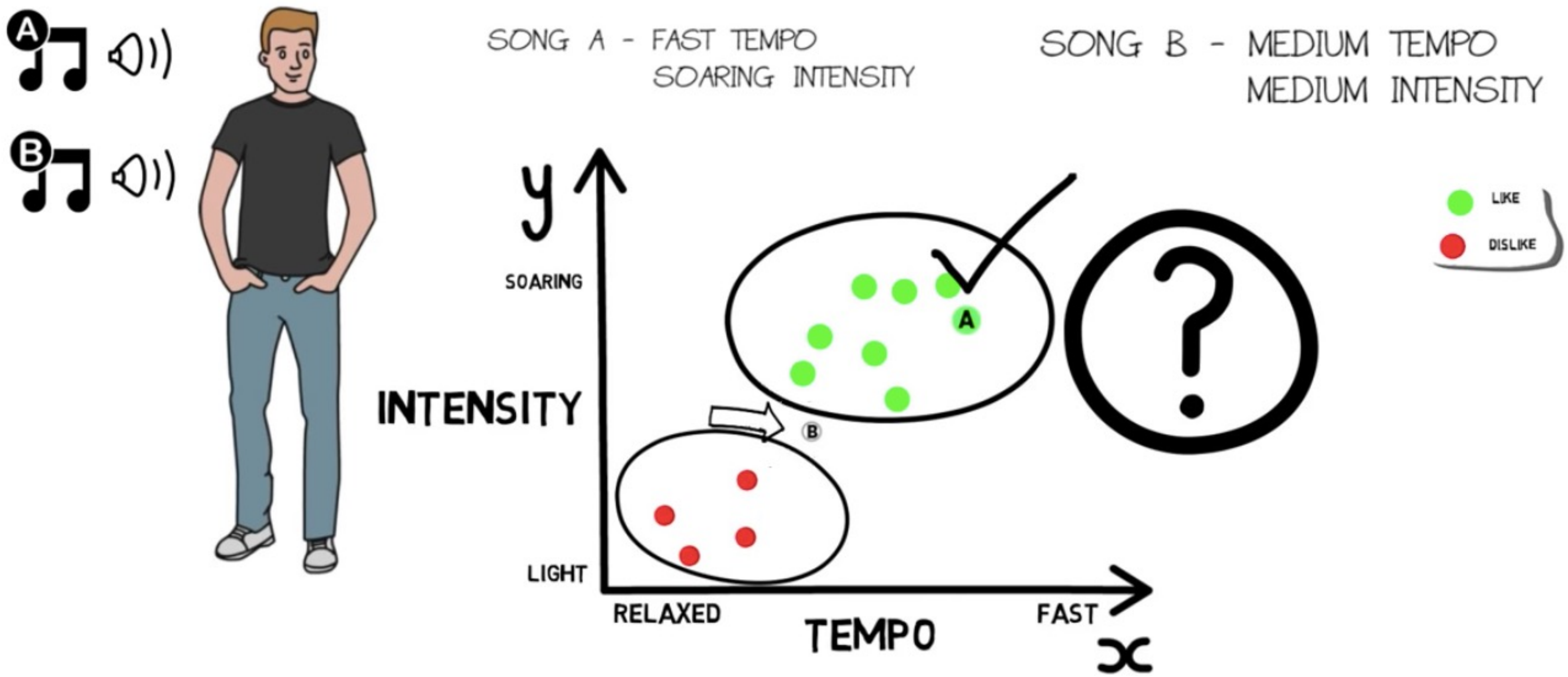

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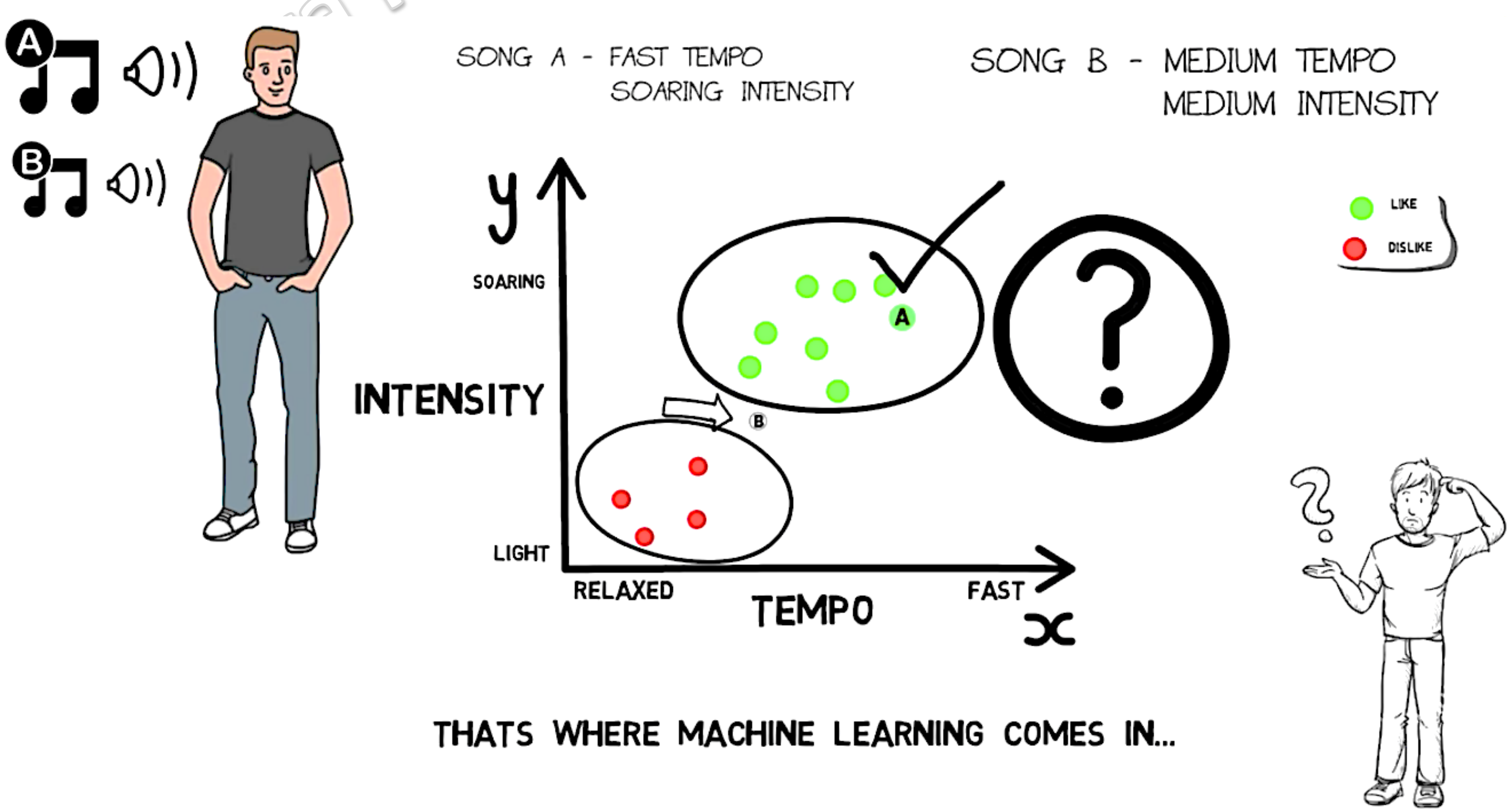
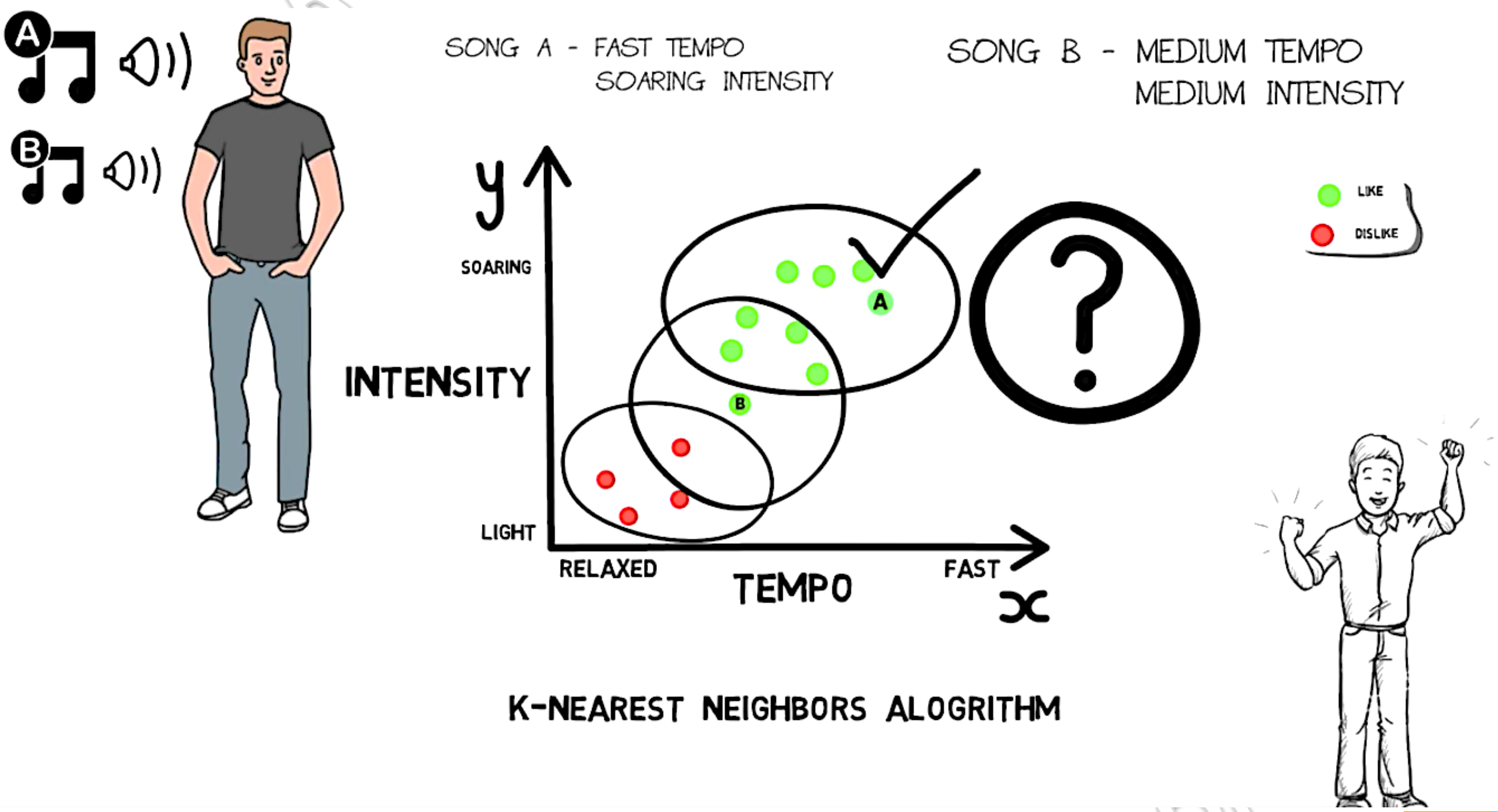


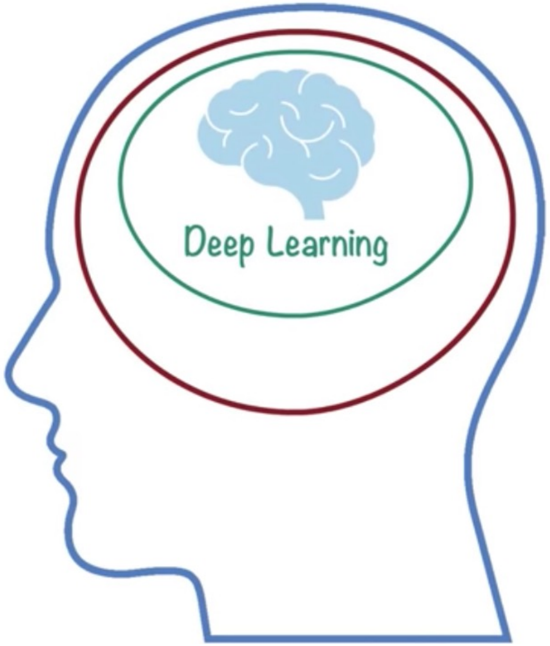
THATS WHERE MACHINE LEARNING COMES IN...

Machine Learning is……



Deep Learning

Deep Learning is.....



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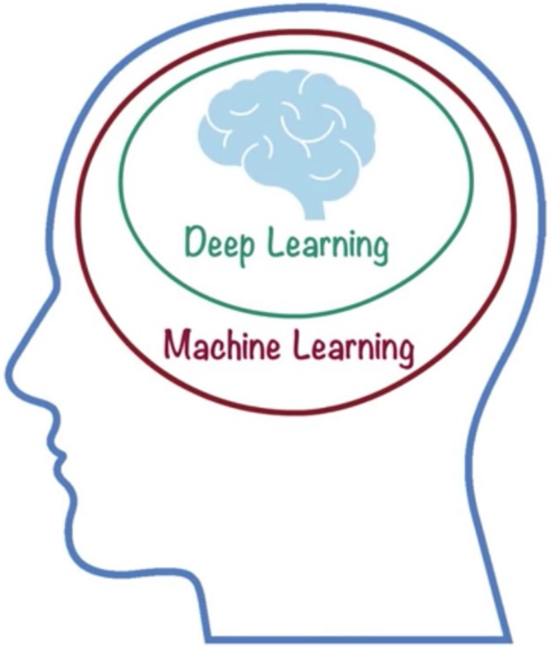

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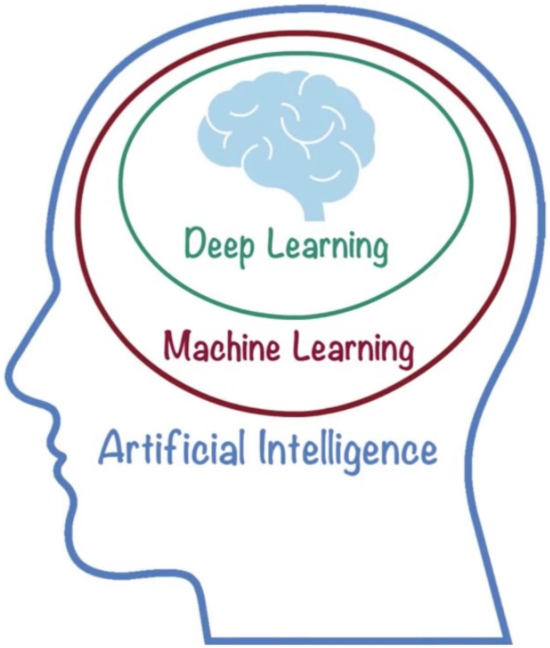

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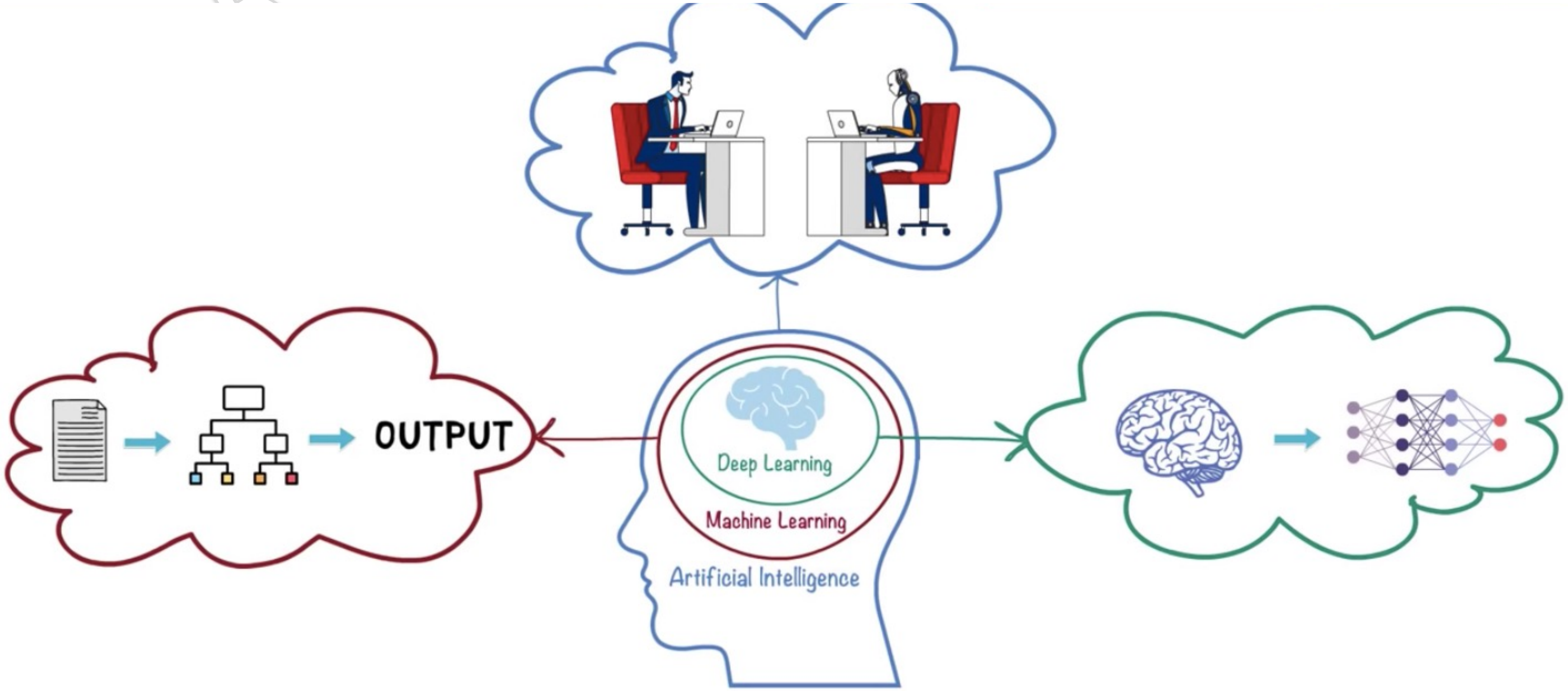
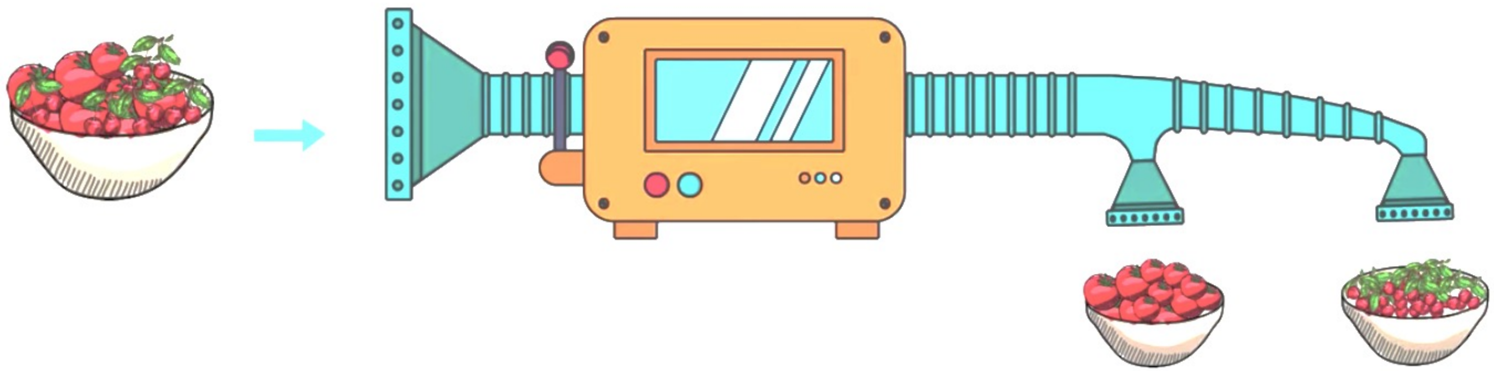


Let's understand deep learning better and how it's different from machine learning

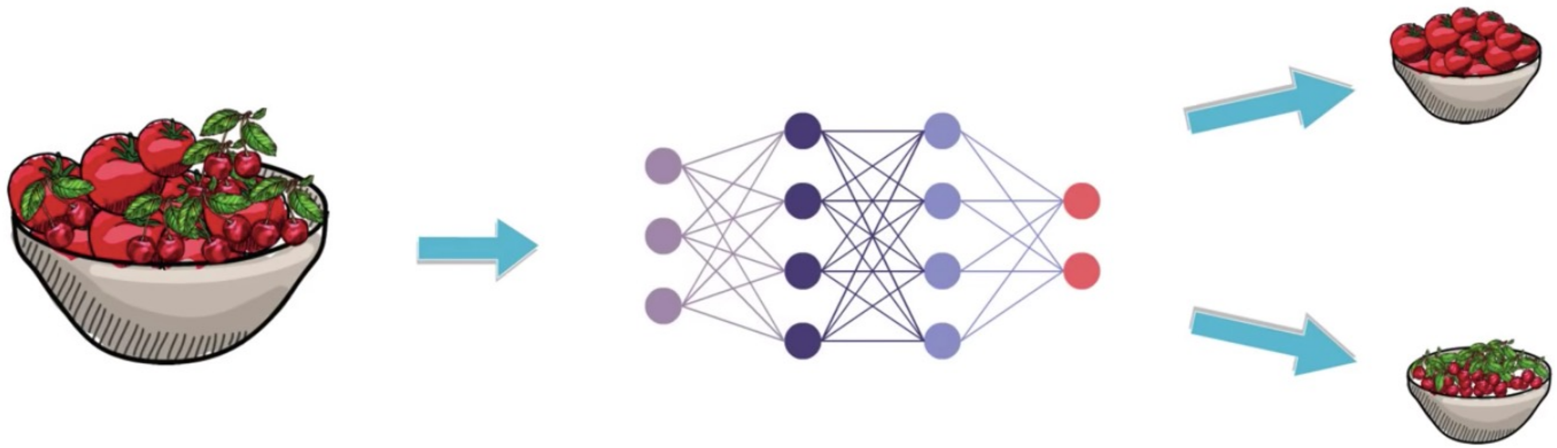
Deep Learning is.....



Deep Learning is.....

Features		
	Tomato	Cherry
Size		
Type of Stem		

Deep Learning is.....



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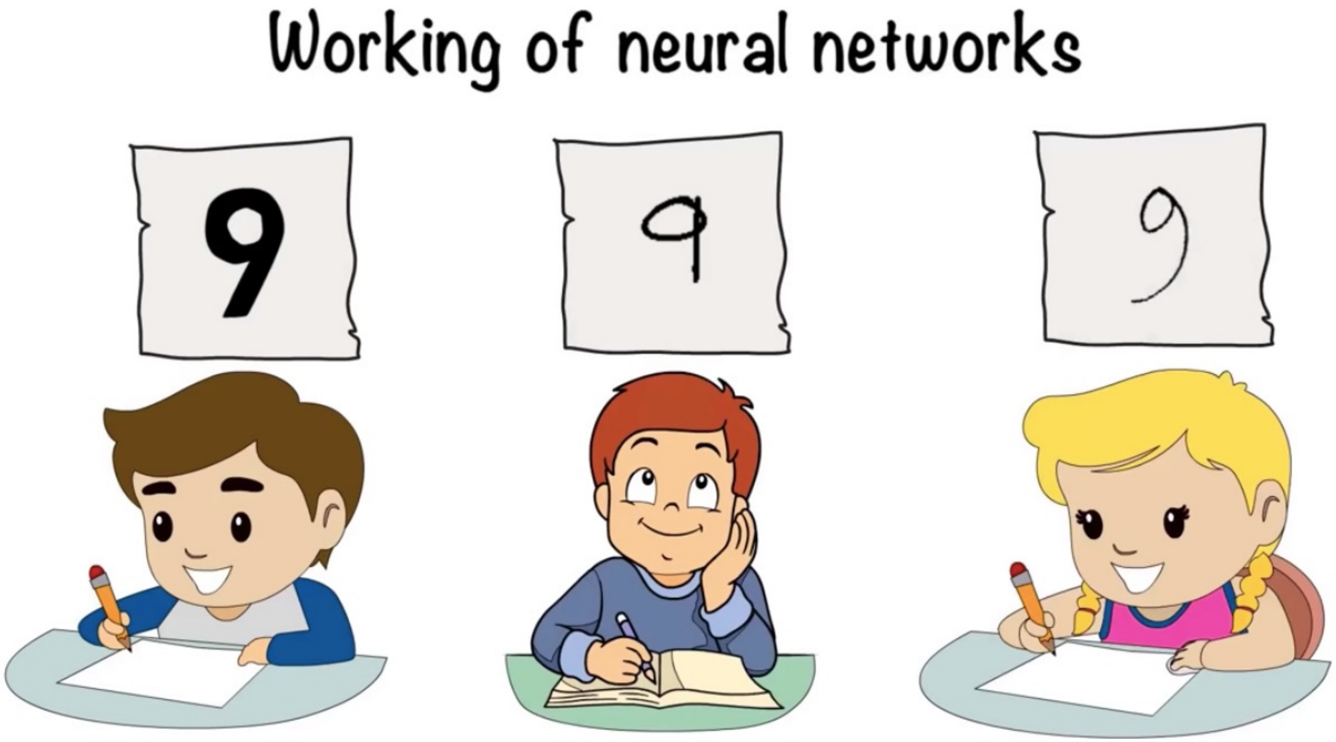

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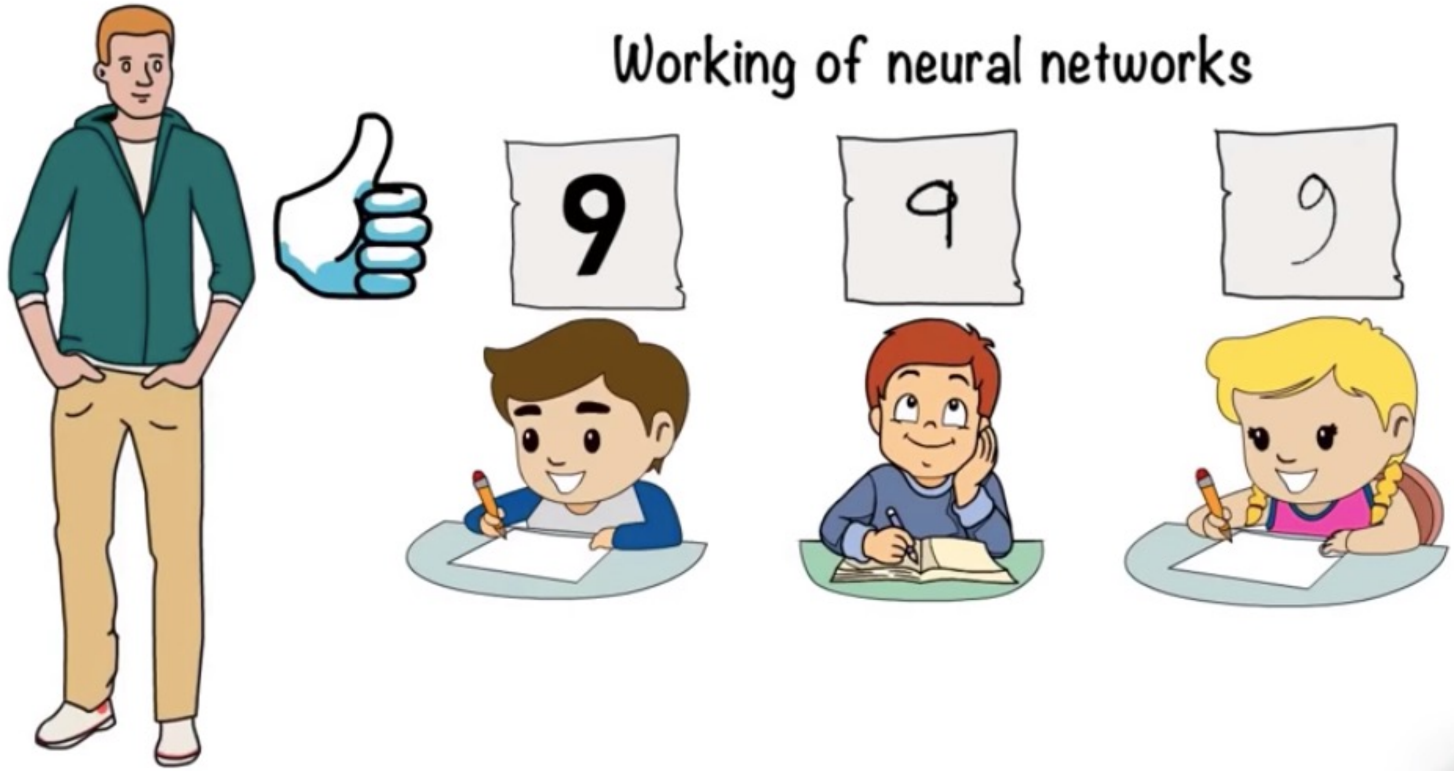

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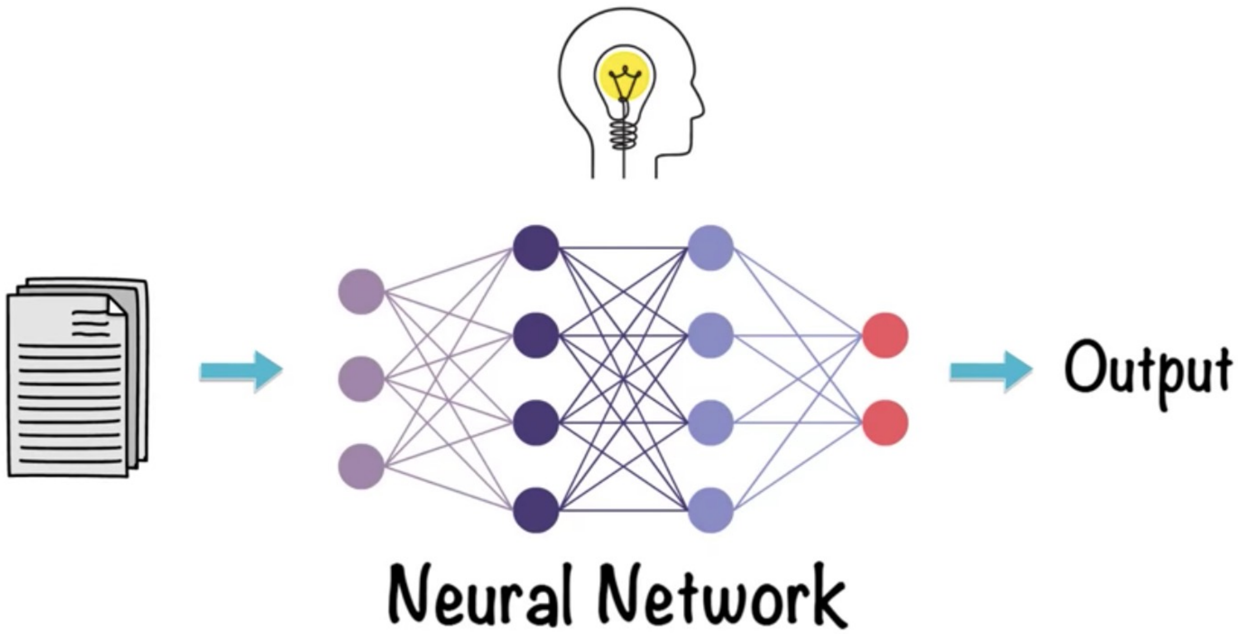
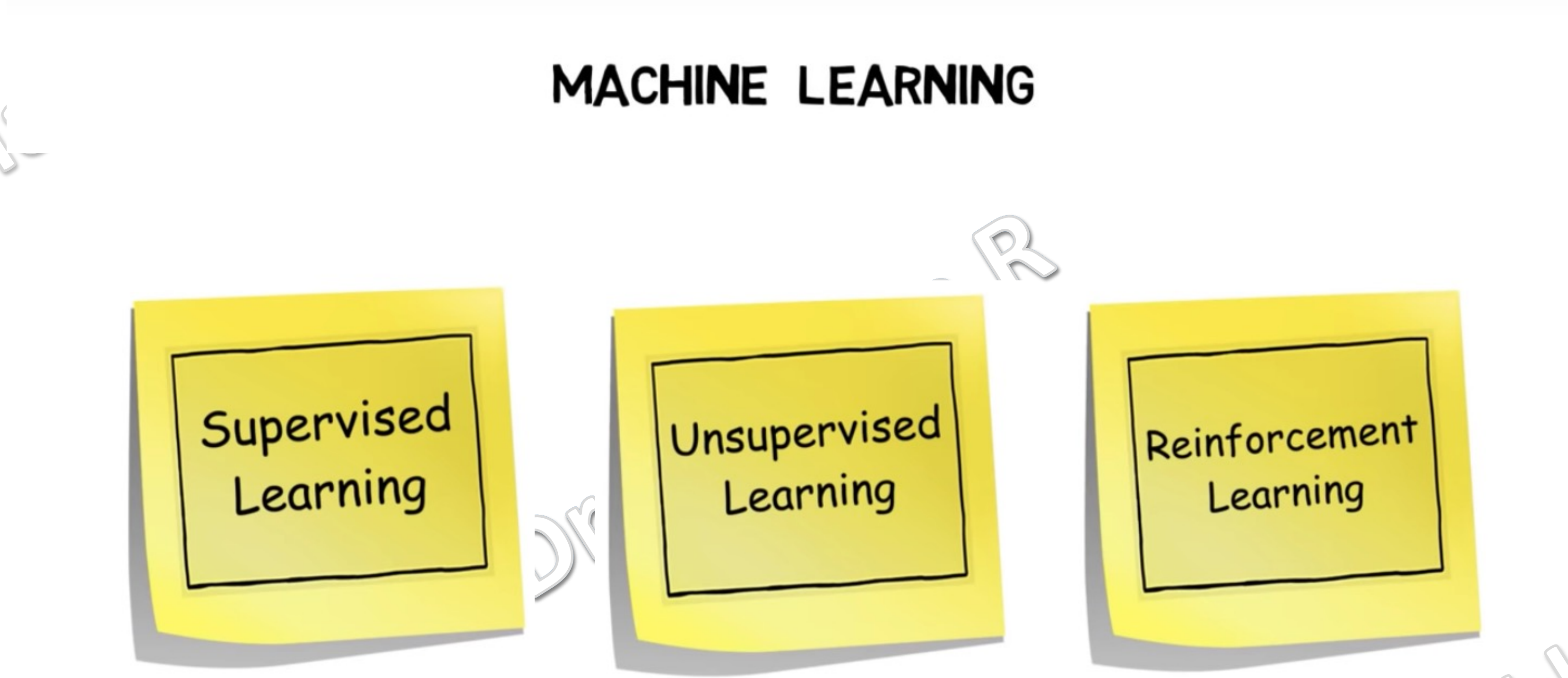
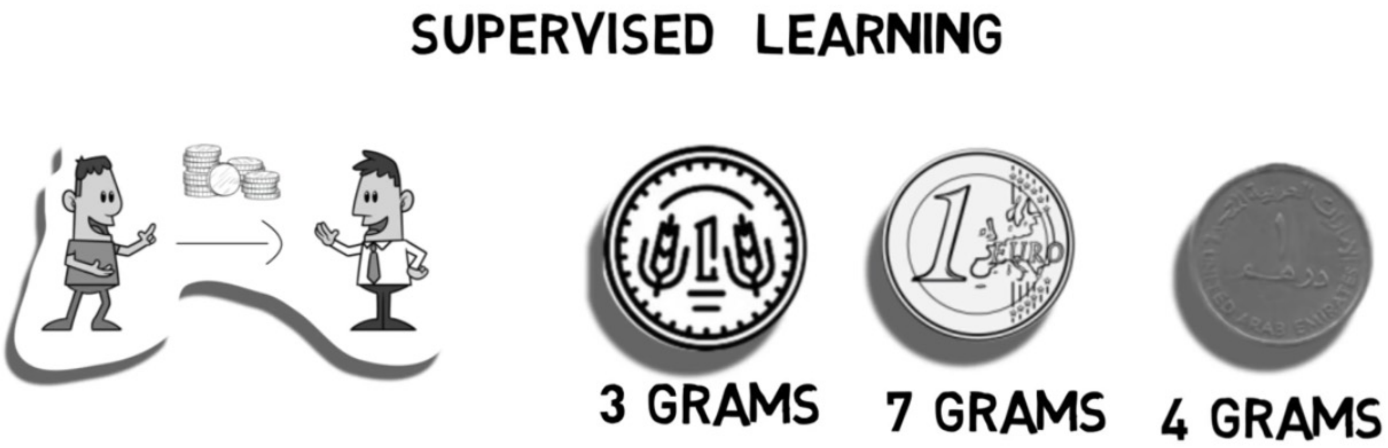


Types

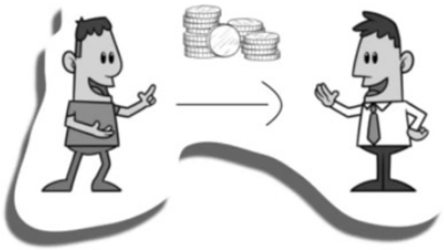

MACHINE LEARNING
Supervised Learning
Unsupervised Learning
Reinforcement Learning

Types



Types

SUPERVISED LEARNING

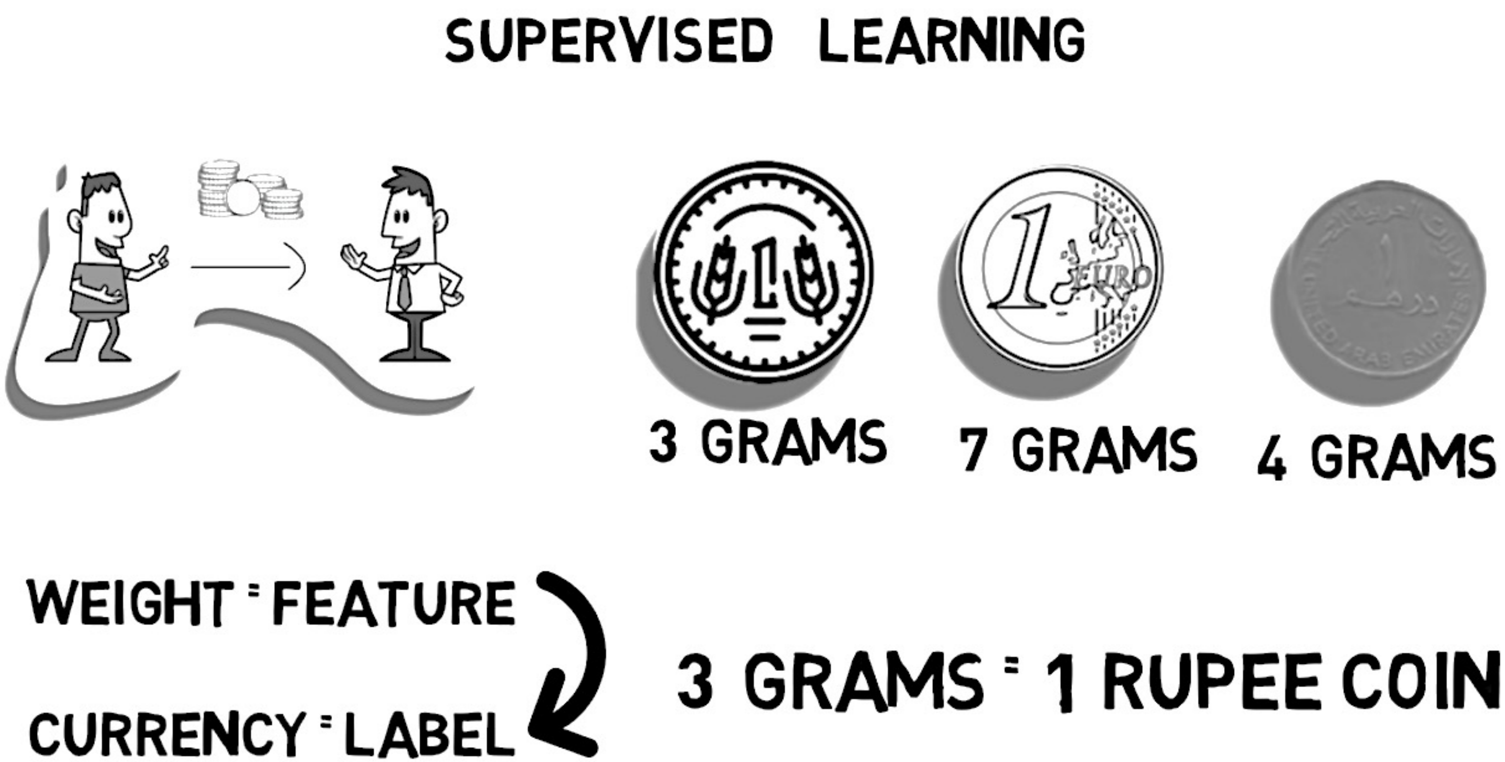


3 GRAMS 7 GRAMS 4 GRAMS

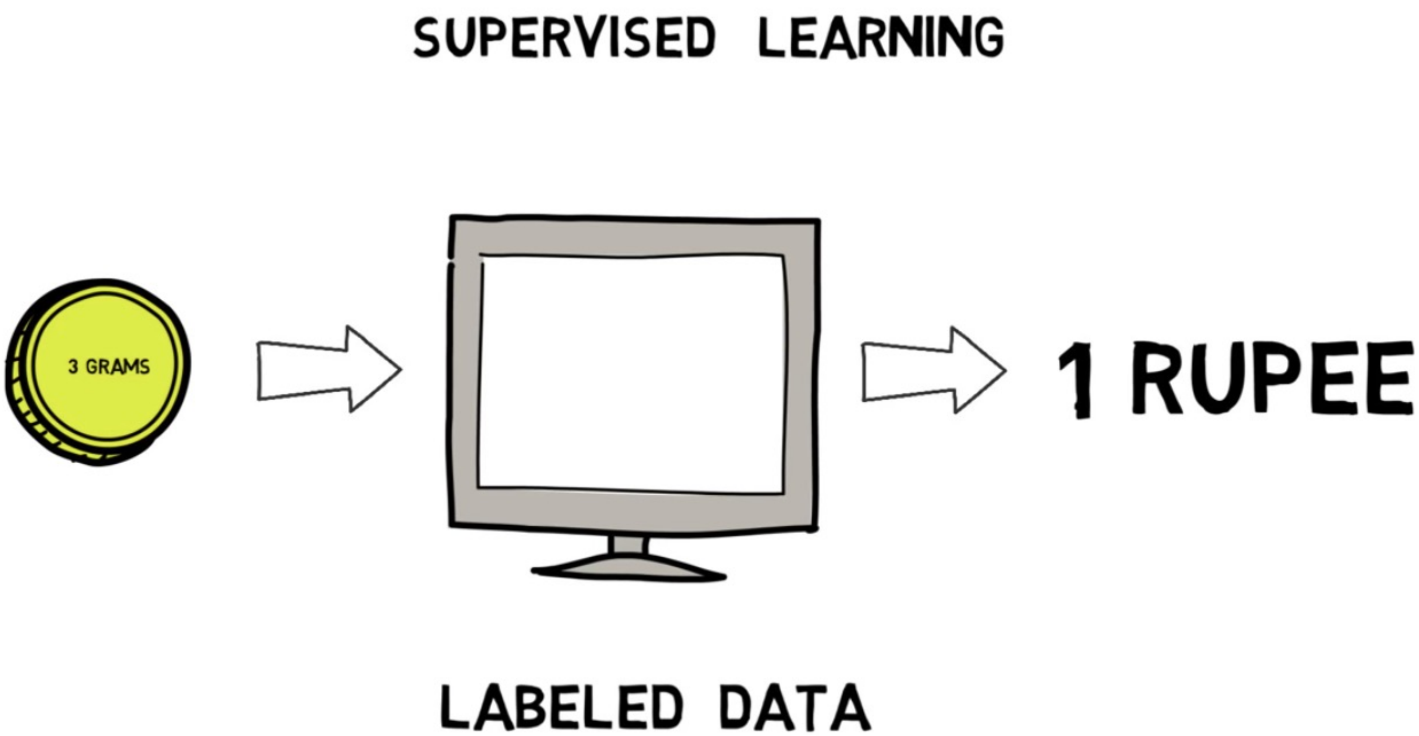
WEIGHT = FEATURE

CURRENCY = LABEL

Types

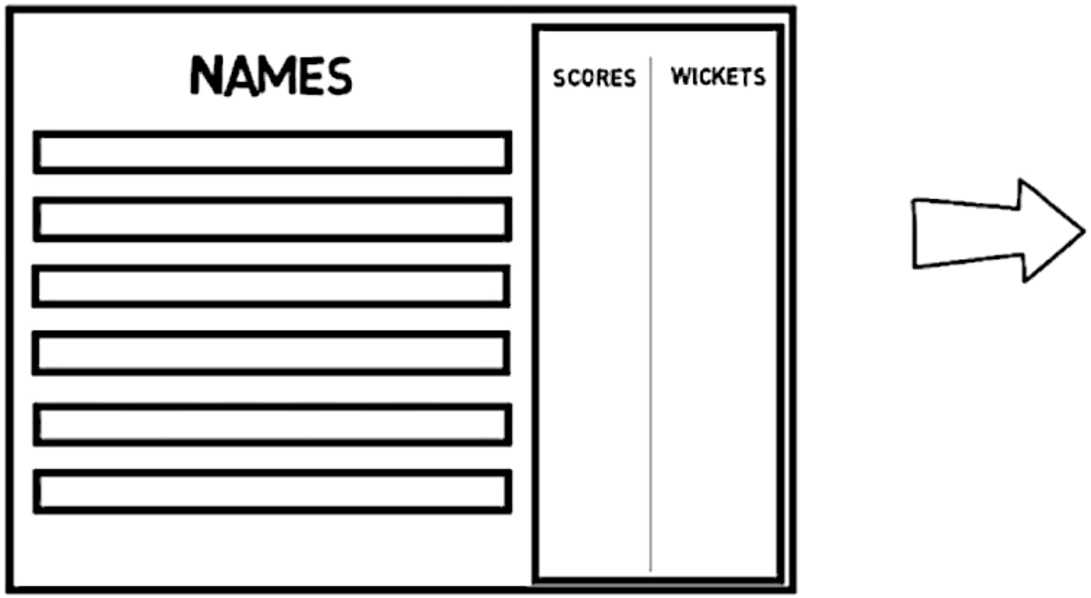

SUPERVISED LEARNING
3 GRAMS
7 GRAMS
4 GRAMS
WEIGHT = FEATURE
CURRENCY = LABEL
3 GRAMS = 1 RUPEE COIN

Types



Types

UNSUPERVISED LEARNING



Types

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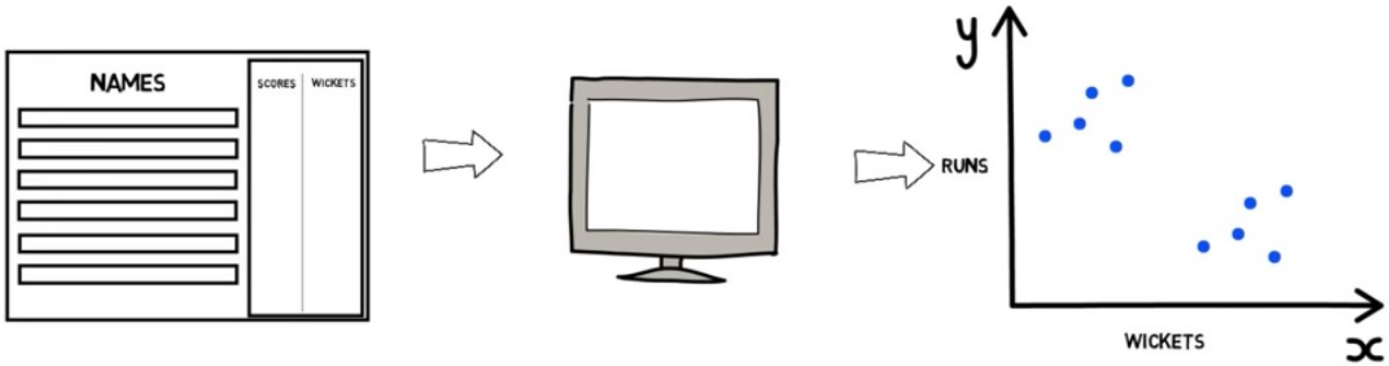

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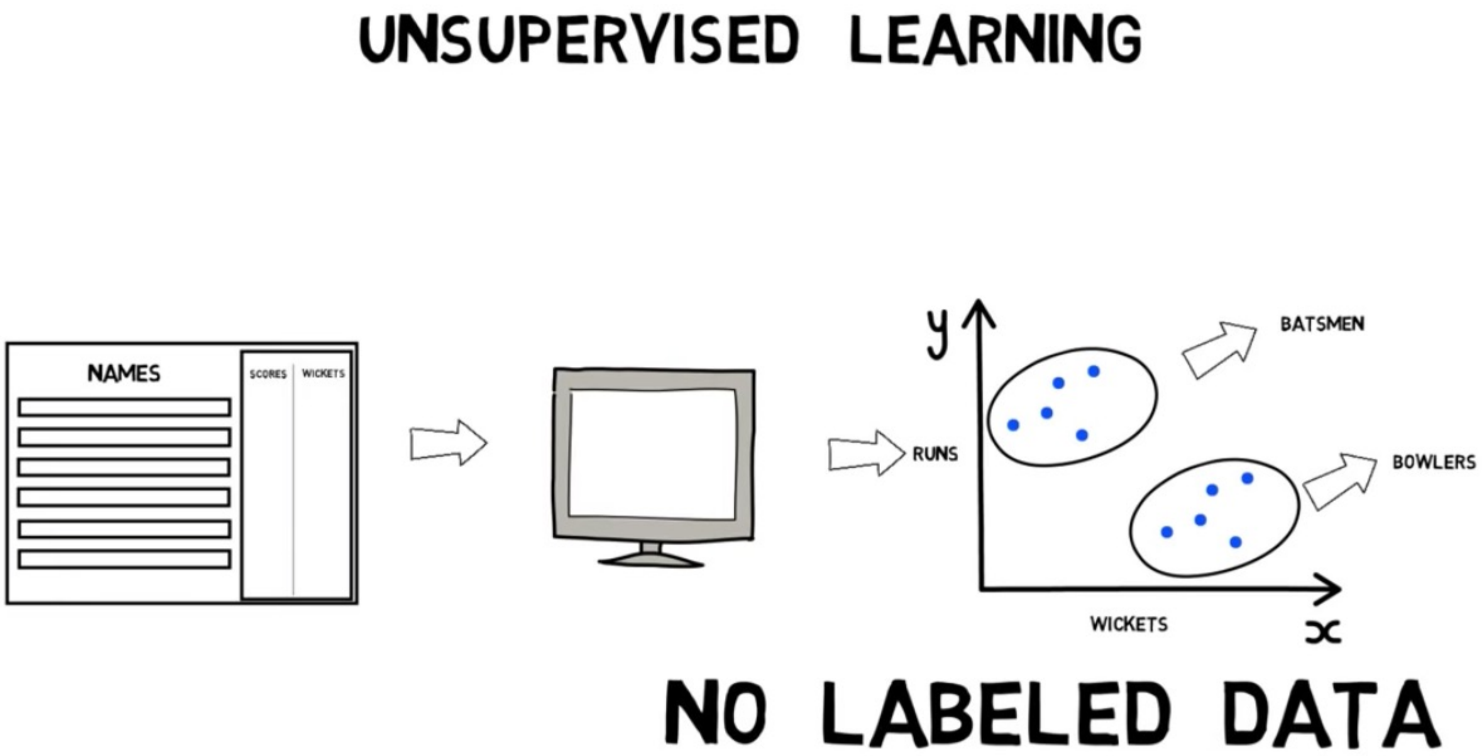
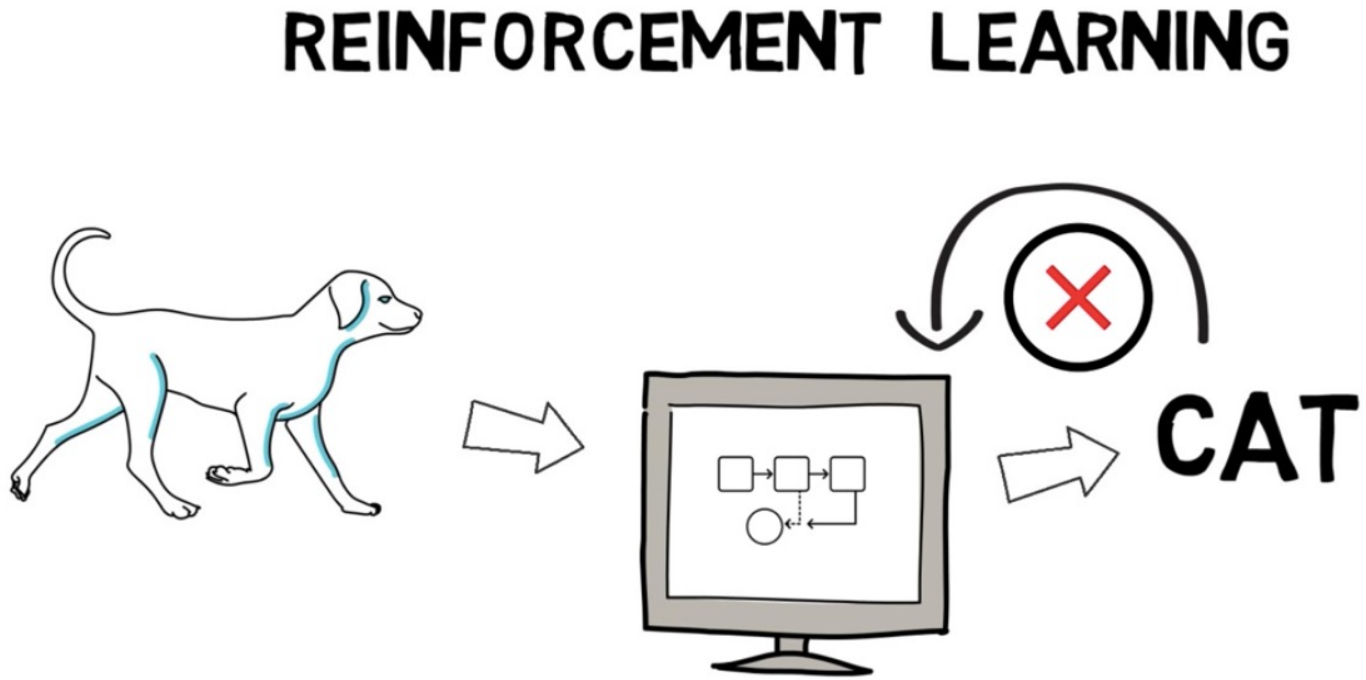

UNSUPERVISED LEARNING
NAMES
SCORES
WICKETS
y
RUNS
BATSMEN
BOWLERS
WICKETS
x
NO LABELED DATA

Types



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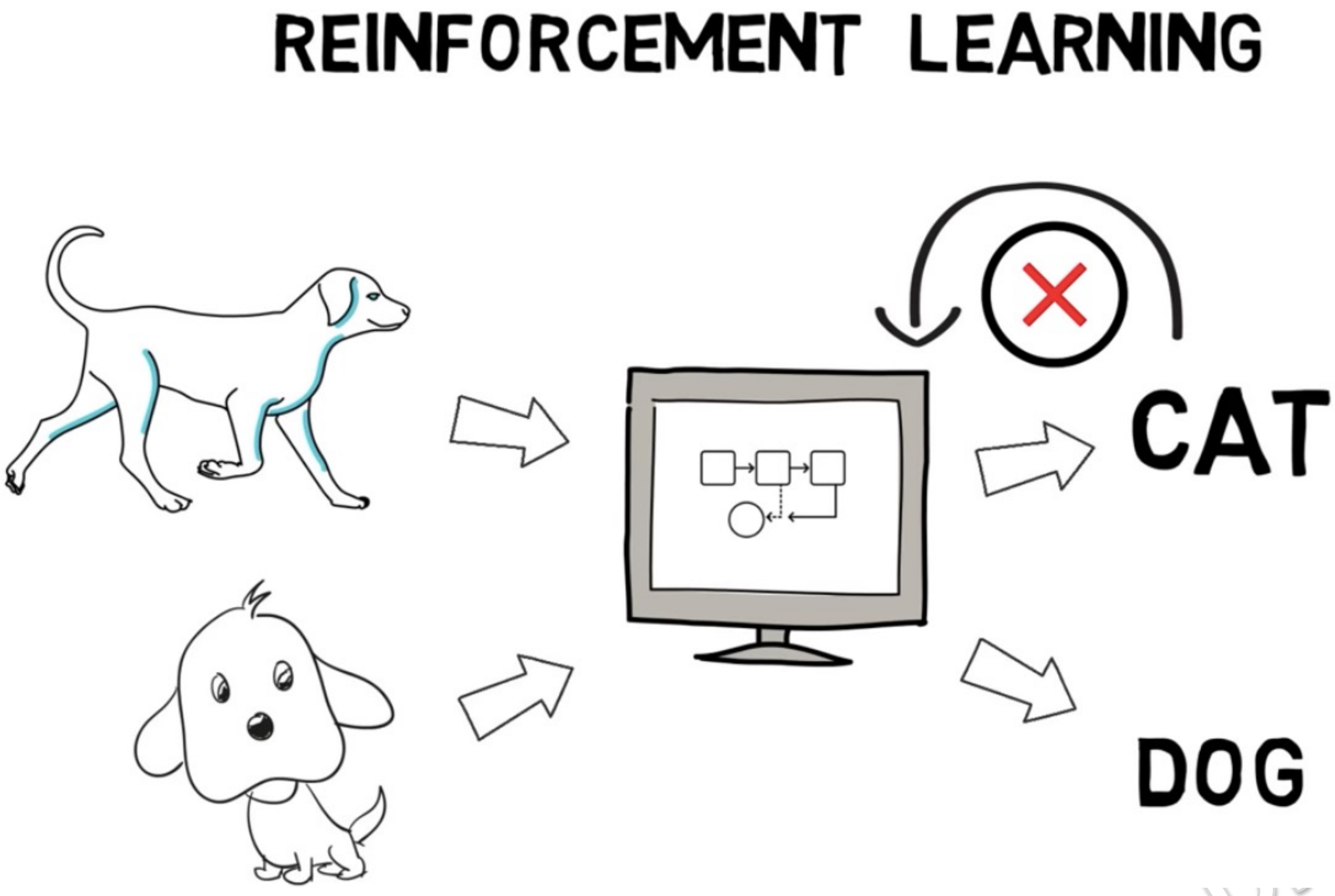

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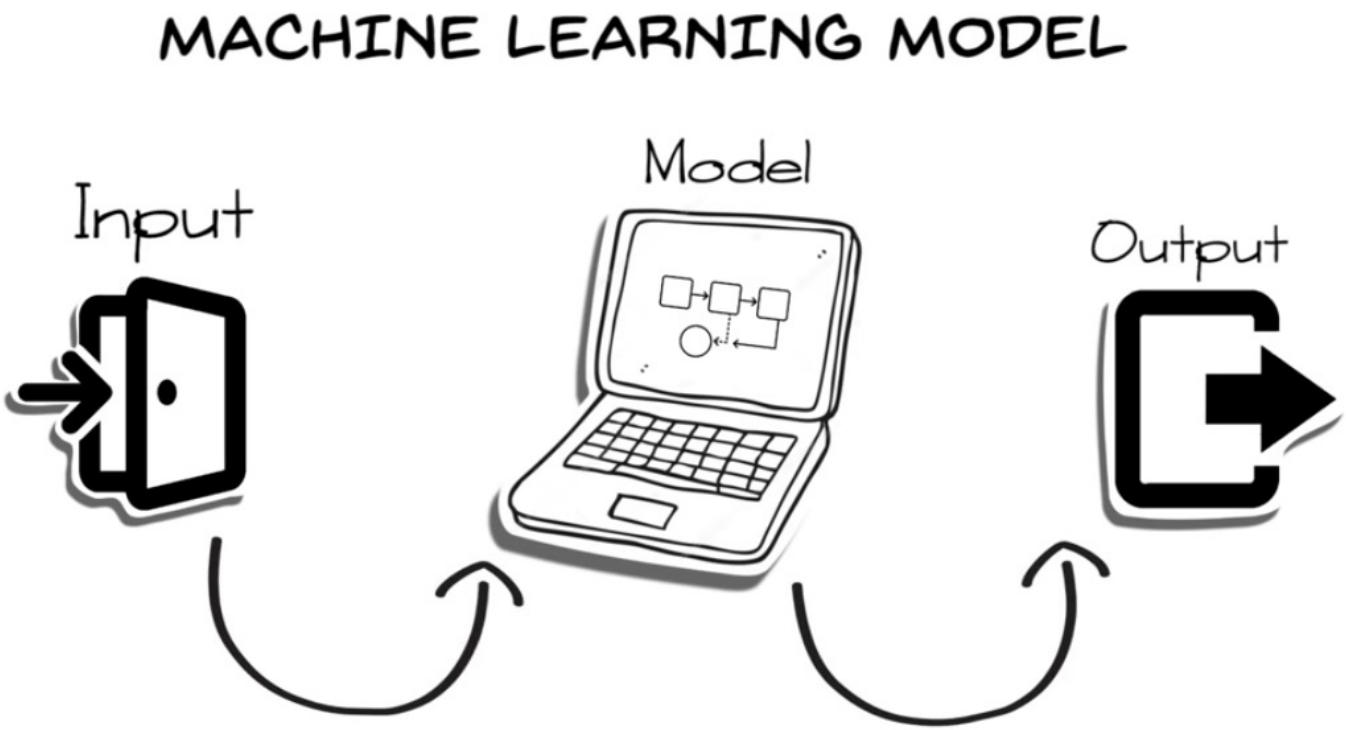

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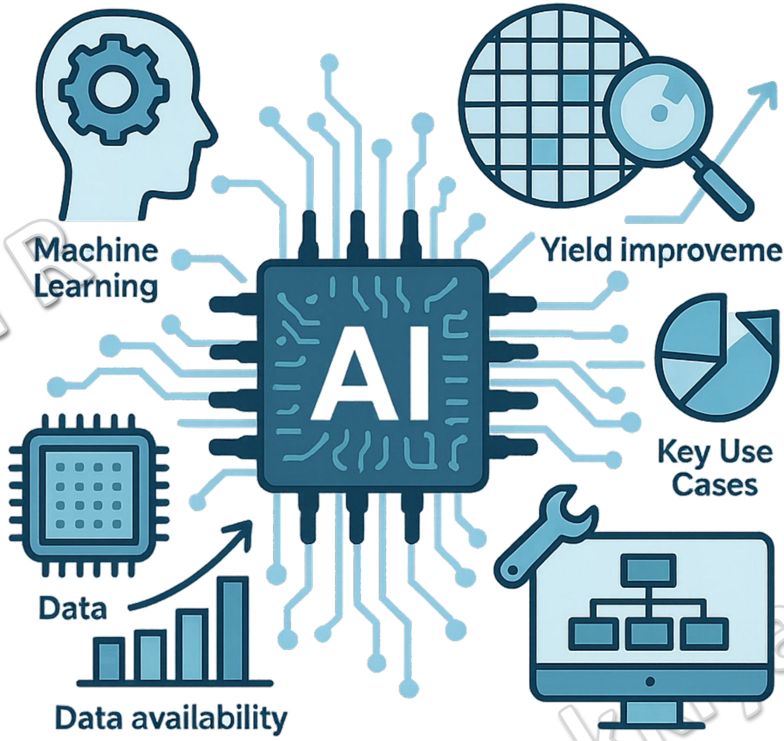


Key AI-Driven Semiconductor Advances

- High-Performance Computing (HPC) Chips:
  - AI demands processing units of the kind of GPUs, TPUs or NPUs, capable of performing many vast calculations at once.
- Edge AI Semiconductors:
  - The increase in IoT devices implies the need for chips that can handle AI computations to minimise some of the latency in real-time decisions.
- AI Accelerator Chips:
  - These customised processors such like ASICs provide rather unique features for certain AI tasks and outdo all the rest.

Data Availability in Semiconductor Industry

- Layout Data
  - Design files: netlists, GDSII layouts, standard cells
  - Used for: design rule checks, lithography simulation, yield modeling
- Process Data
  - Parameters from fabrication: temperature, pressure, etch time, CMP rates
  - Used for: anomaly detection, yield prediction
- Equipment Logs
  - Sensor outputs, tool health, throughput stats
  - Used for: predictive maintenance and tool diagnostics
- Defect Data
  - SEM / optical inspection images, defect location maps, classification tags
  - Used for: defect detection/classification via deep learning
- Test & Yield Data
  - Parametric test results, pass/fail logs
  - Used for: correlating upstream conditions with final chip quality

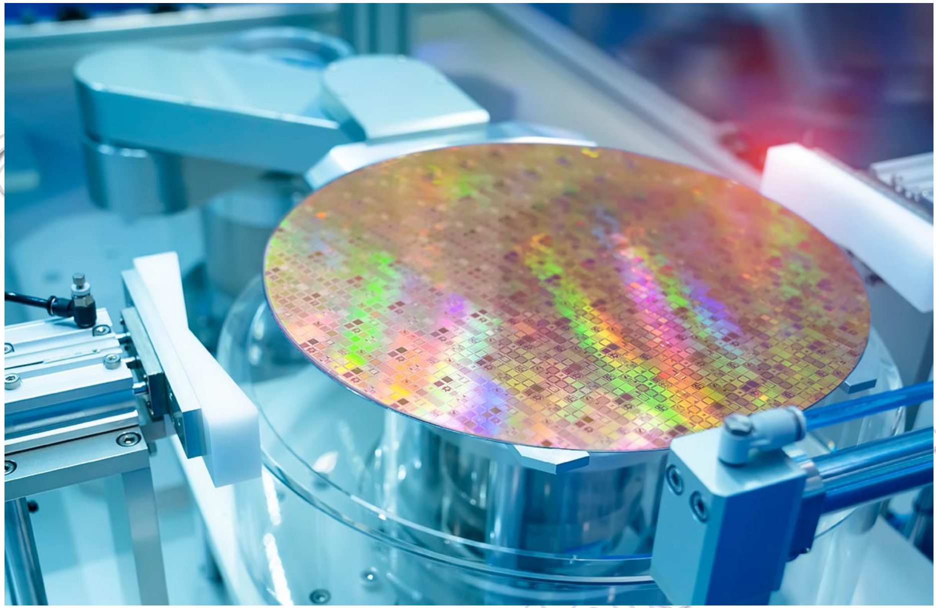
1: Wafer Inspection and Defect Detection

- Traditional inspection is manual or rule-based
  - Time-consuming, subjective, prone to human error

- AI (especially CNNs) enables:
  - Real-time image classification of SEM/optical wafer images
  - Localization of surface defects (scratches, particles, pattern issues)
  - Higher accuracy and consistency

- Trained on thousands of labeled defect images
  - Models learn to generalize across new defect patterns

- Result:
  - Reduced inspection time
  - Increased defect classification accuracy
  - Automated feedback to process teams



AI models detect and classify defects from SEM and optical images in real time, boosting both speed and precision.

2: Yield Prediction and Optimization

- Semiconductor yield is influenced by hundreds of variables
  - Layout features, process parameters, tool performance, environmental noise
- AI models (e.g., regression, ensemble methods, neural nets):
  - Learn complex, non-linear relationships between inputs and final yield
  - Identify hidden correlations across fab runs
- Enables early prediction of low-yield wafers or dies
  - Allows proactive intervention and tuning
- Also used for binning optimization and adaptive recipe control
- Outcome:
  - Better yield forecasting
  - Reduced scrap and rework
  - Continuous process improvement

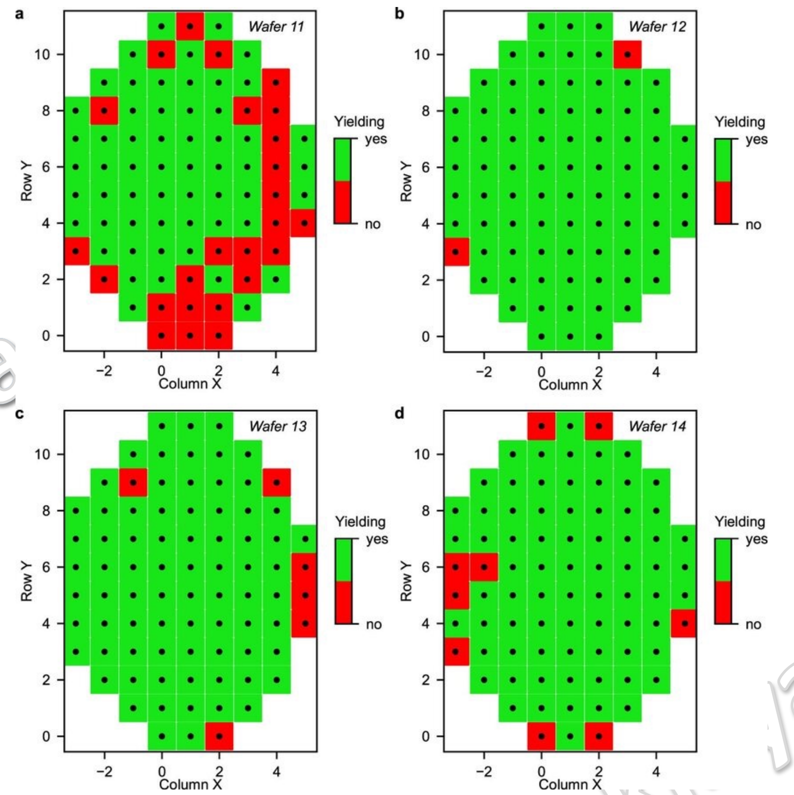


Image Source: Qubits made by advanced semiconductor manufacturing

AI-driven yield models learn from historical fab data to forecast chip success or failure before final test.

3: Process Control and Monitoring

- Semiconductor fabs involve complex multistep processes (etching, deposition, doping, etc.)
  - Each process stage generates real-time sensor data:
  - Temperature, pressure, flow rates, time-series metrics
- AI enables:
  - Anomaly detection in inline processes
  - Real-time parameter tuning to stabilize drift
  - Statistical Process Control (SPC) with ML-driven thresholds
- ML models (e.g., LSTMs, autoencoders) detect deviations early — even before traditional alarms are triggered
- Outcome:
  - Minimized excursions
  - Improved process stability and tool uptime
  - Fewer defective wafers downstream

Image Source: Plasma sheath modelling to predict etch-induced overlay

AI models continuously monitor process data to catch drift and anomalies in real time, enabling predictive control.

4: Predictive Maintenance for Fab Equipment

- Semiconductor equipment (litho, etch, CMP, etc.) is highly specialized and expensive
  - Downtime = major productivity and cost loss
- Traditional maintenance is schedule-based or reactive
  - May result in over-maintenance or unexpected failures
- AI-based predictive maintenance uses:
  - Equipment sensor logs (vibration, temperature, pressure, current)
  - Operational data (throughput, cycle count, usage trends)
- ML models (e.g., random forests, LSTMs, survival models) predict failure likelihood
  - Maintenance is triggered just-in-time
- Outcome:
  - Reduced unplanned downtime
  - Extended equipment life
  - Lower maintenance costs

AI enables proactive maintenance by learning degradation patterns from historical equipment data.

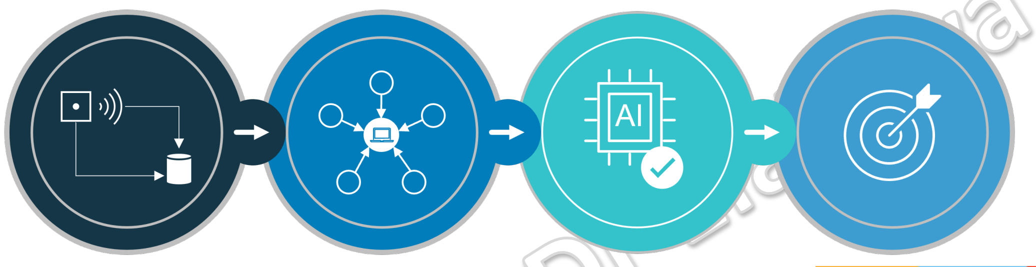


Image Source: techovedas.com

5: Equipment and Resource Optimization

- Modern fabs operate with hundreds of interdependent tools
  - Scheduling, calibration, recipe tuning impact fab throughput
- AI-driven optimization helps:
  - Assign wafers to the best-suited tools based on historical performance
  - Optimize tool utilization to prevent bottlenecks
  - Recommend recipe adjustments based on yield trends
- Reinforcement Learning (RL) and Bayesian optimization used for:
  - Multi-objective trade-offs: power, cycle time, quality
  - Learning from feedback: reward = better fab KPIs
- Outcome:
  - Better fab scheduling
  - More consistent wafer quality across toolsets
  - Reduced rework and queue time

AI allocates wafers and calibrates tools to maximize throughput and maintain quality across the fab floor.

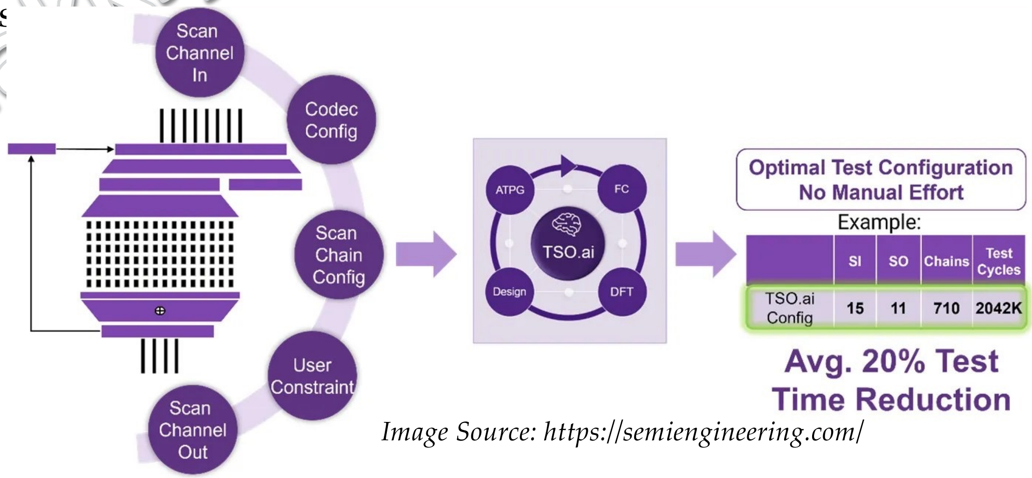


Image Source: https://semiengineering.com/

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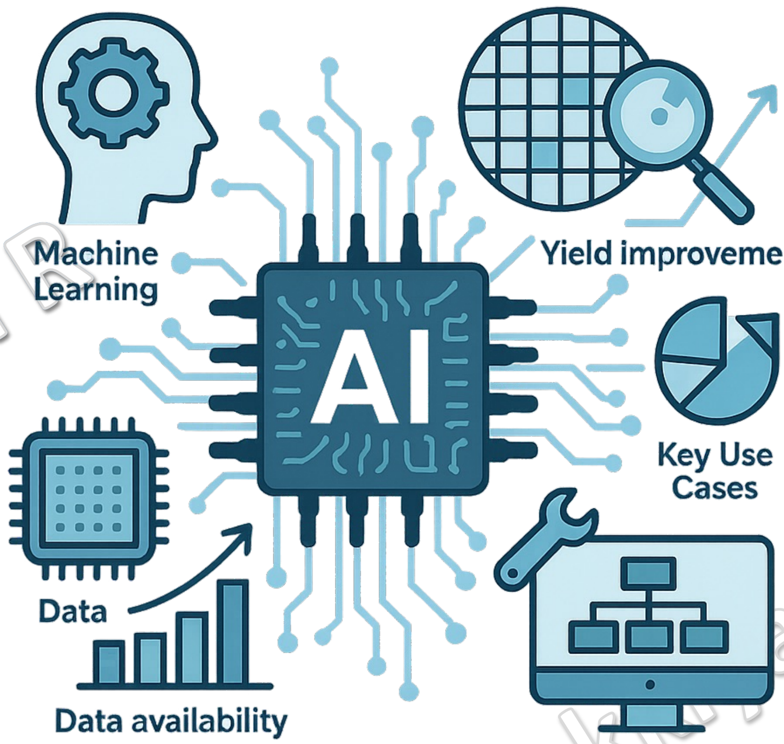
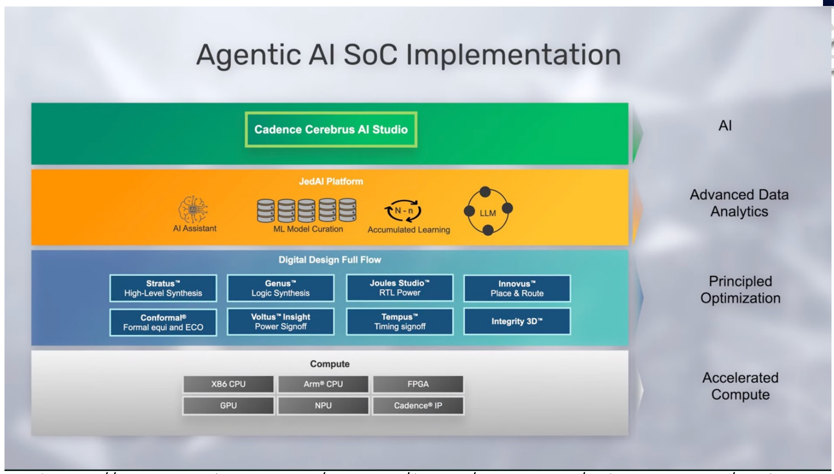
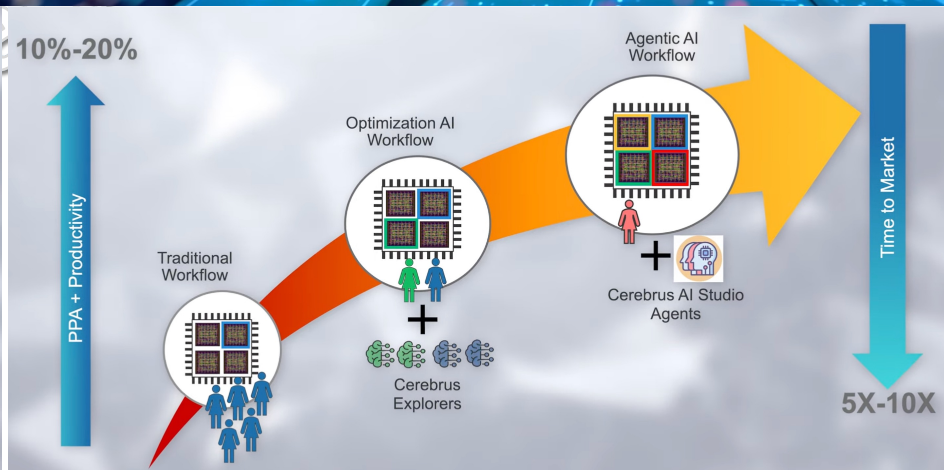


Real Time Tools

Cadence Cerebrus AI Studio





Source: https://www.cadence.com/en_US/home/resources/white-papers/cadence-cerebrus-ai-studio-agentic-ai-multi-block-multi-user-soc-wp.html

Real Time Tools

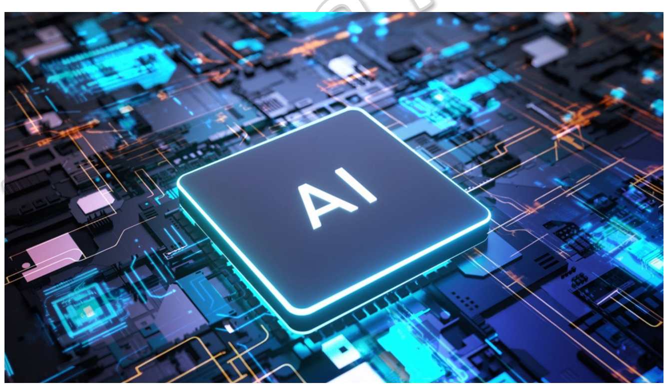
Synopsys.ai™: AI-Driven Optimization Across Full-Stack

For design, verification, testing & manufacturing of digital and analog chips

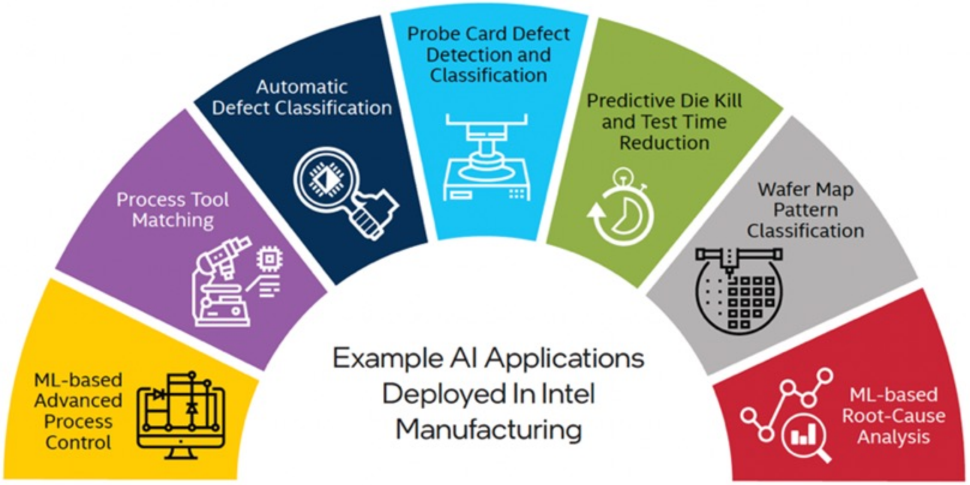
SYNOPSYS

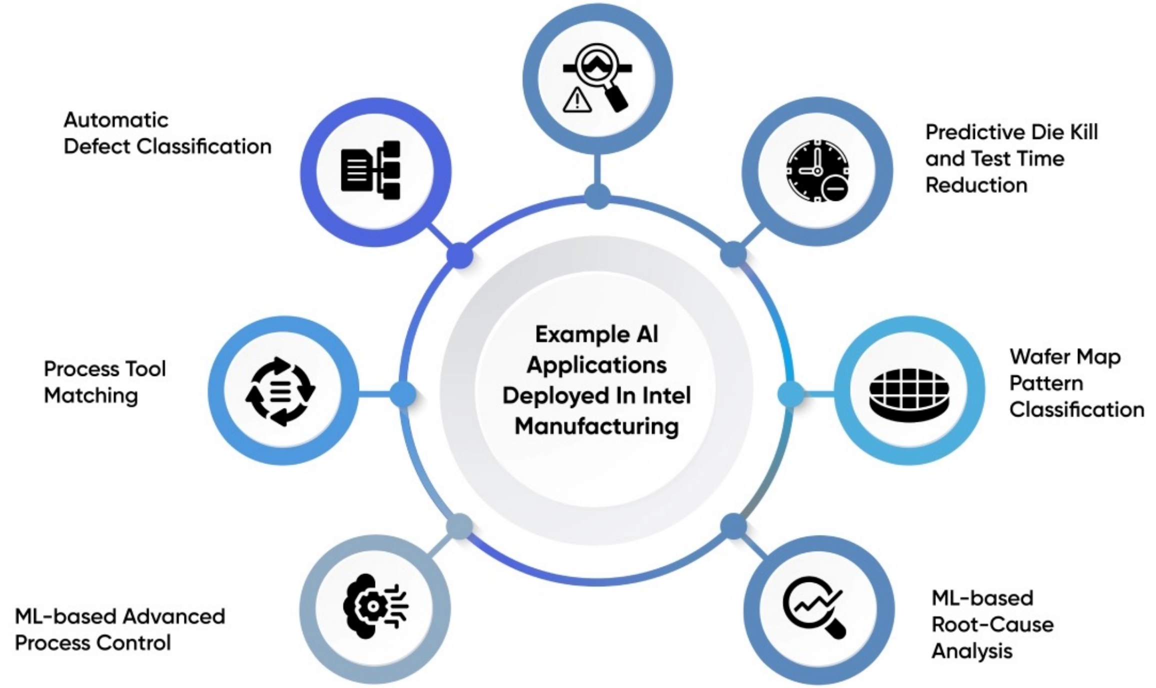
Source: https://www.synopsys.com/ai/ai-powered-eda/videos.html

Real Time Tools



Intel AI





Source: https://community.intel.com/

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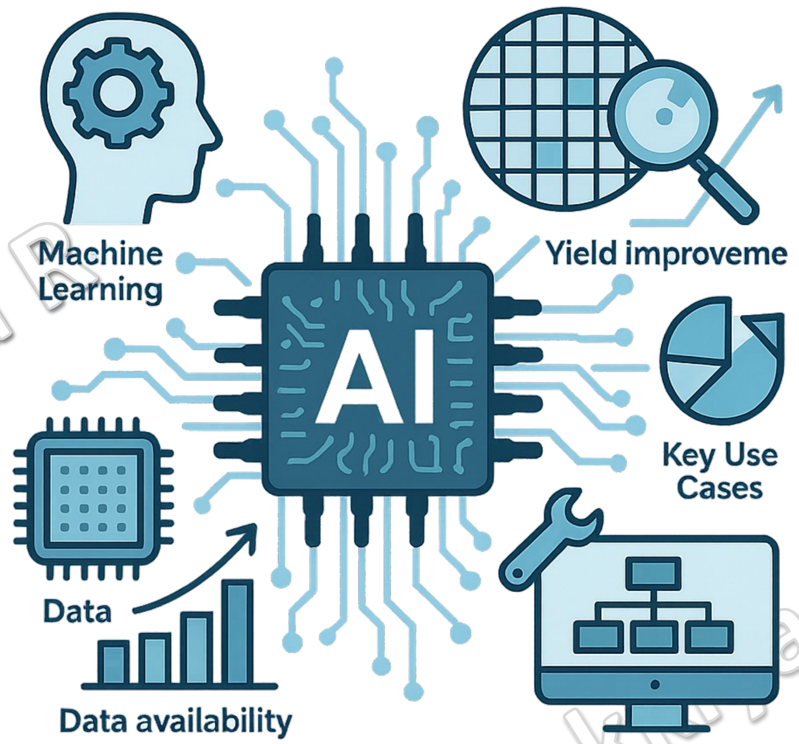

Challenges in Adopting AI in Semiconductor

- Data Privacy and IP Protection
  - Layouts, process flows, and defect maps are highly sensitive
  - Sharing across vendors or cloud services poses security risks
- Labeling and Data Quality Issues
  - Incomplete or inconsistent labeling of defect images, process logs
  - Noisy sensor data and process drift affect model reliability
- Model Interpretability
  - Black-box AI decisions raise concerns in safety-critical operations
  - Engineers need explainable outputs to trust AI in fab workflows
- Integration with Legacy Systems
  - Fab tools often run on decades-old software
  - AI solutions must interoperate without disrupting certified flows
- High Cost of Model Maintenance
  - Continuous updates needed as fab conditions change
  - Retraining with new process nodes, recipes, tools

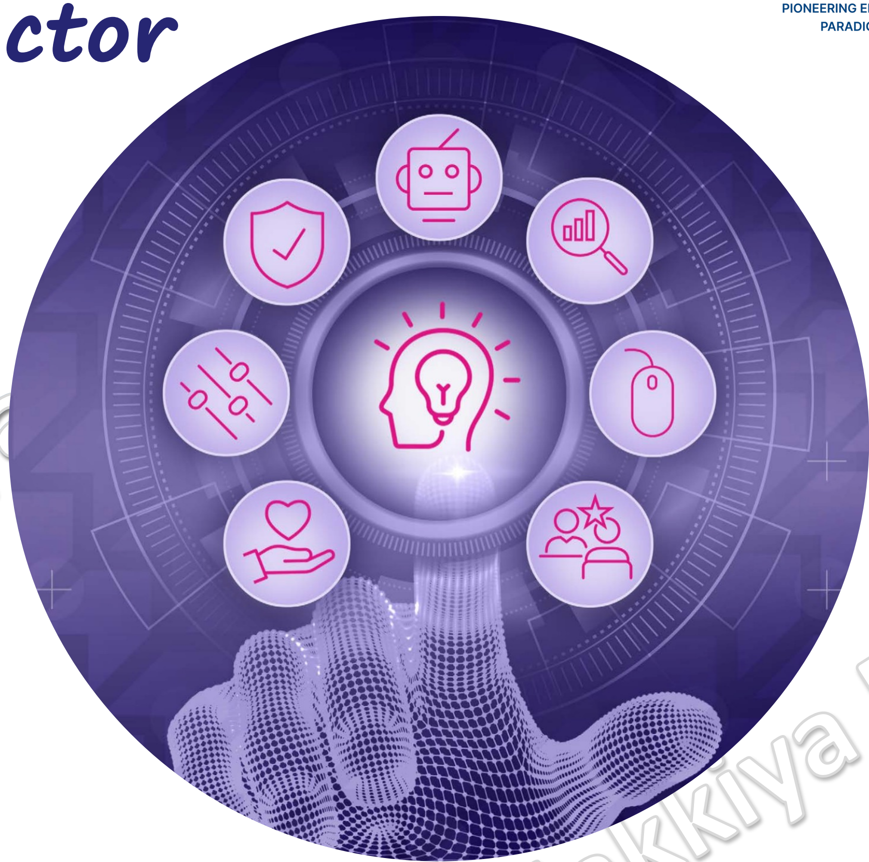

Image Source: https://financialservicesskills.org/

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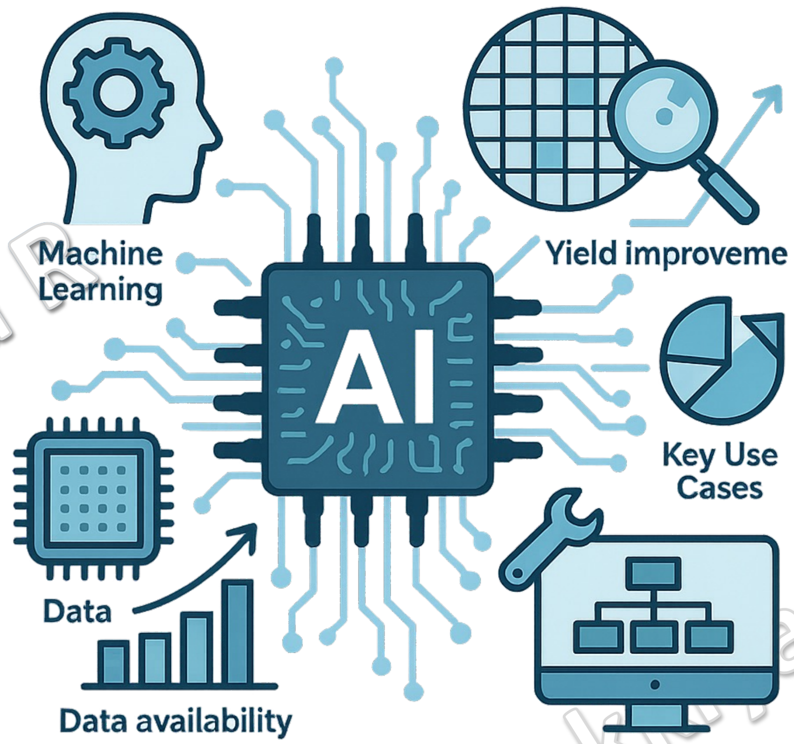
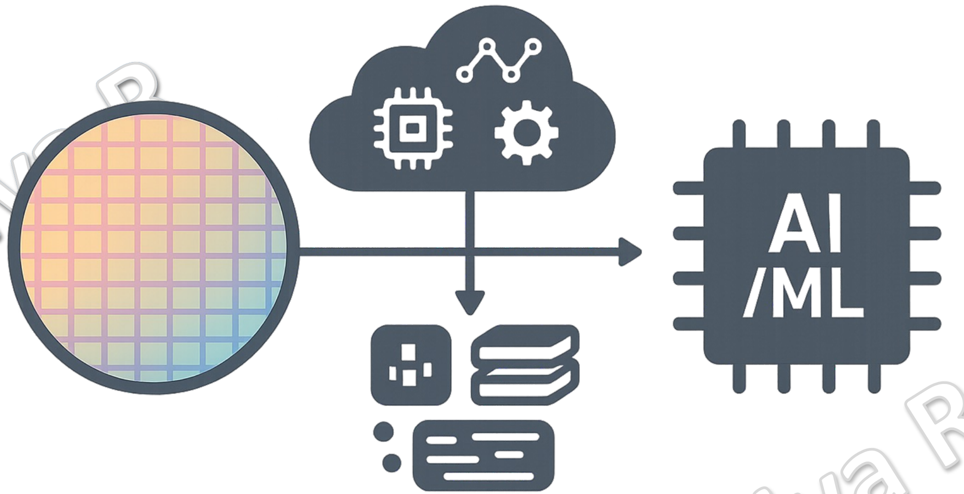


Summary

- AI is transforming semiconductor workflows
  - From design to testing, AI improves speed, accuracy, and yield
- Key use-cases we explored today:
  - Wafer defect detection using CNNs
  - Yield prediction using supervised learning
  - Process control and monitoring via anomaly detection
  - Predictive maintenance from sensor logs
  - Equipment optimization through smart scheduling
  - Supply chain resilience with AI forecasting
- Real-world tools in action:
  - Cadence Cerebrus, Synopsys DSO.ai, Intel's AI pipelines
- Challenges exist, but the benefits are already real and measurable



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Thank You!