Asset Allocation, Machine Learning and High-Performance Computing

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Macro Systematic Strategies, Aberdeen Standard Investments

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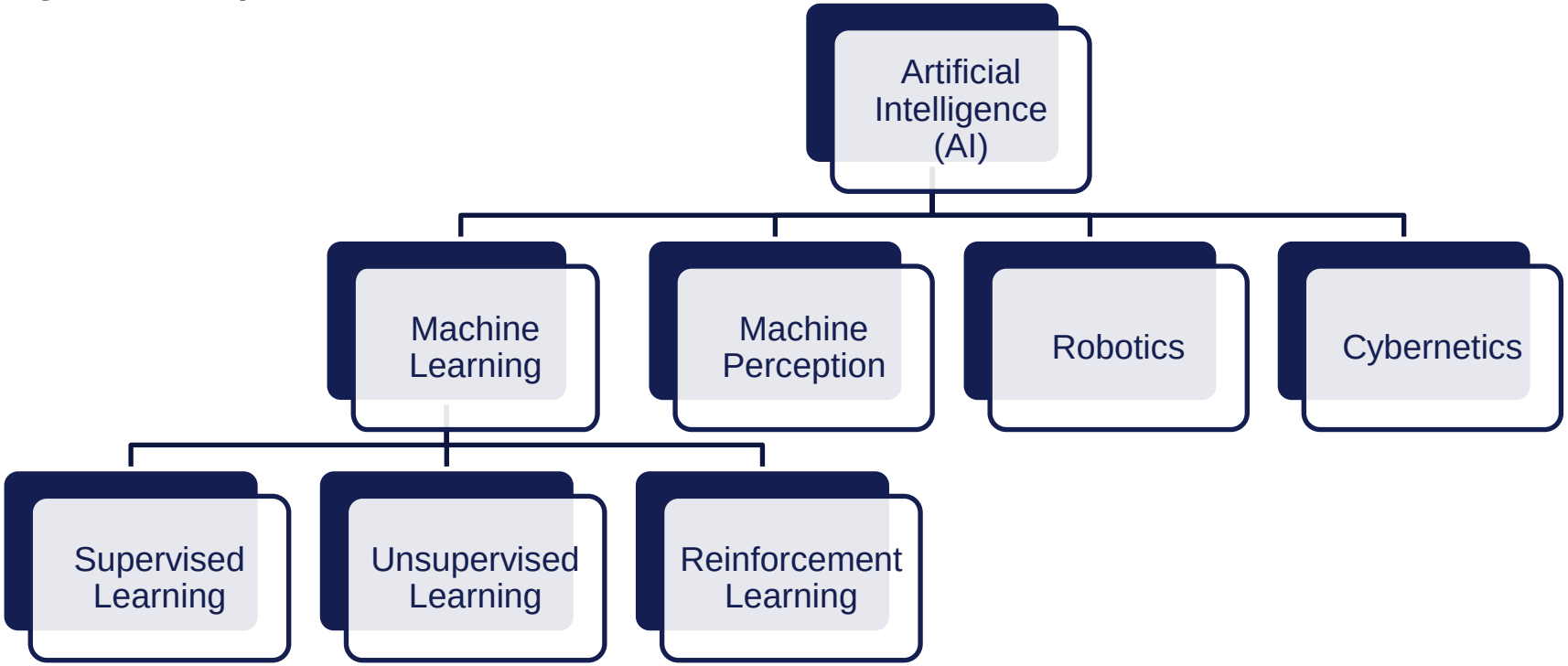
Introduction to Machine Learning

What is Machine Learning?

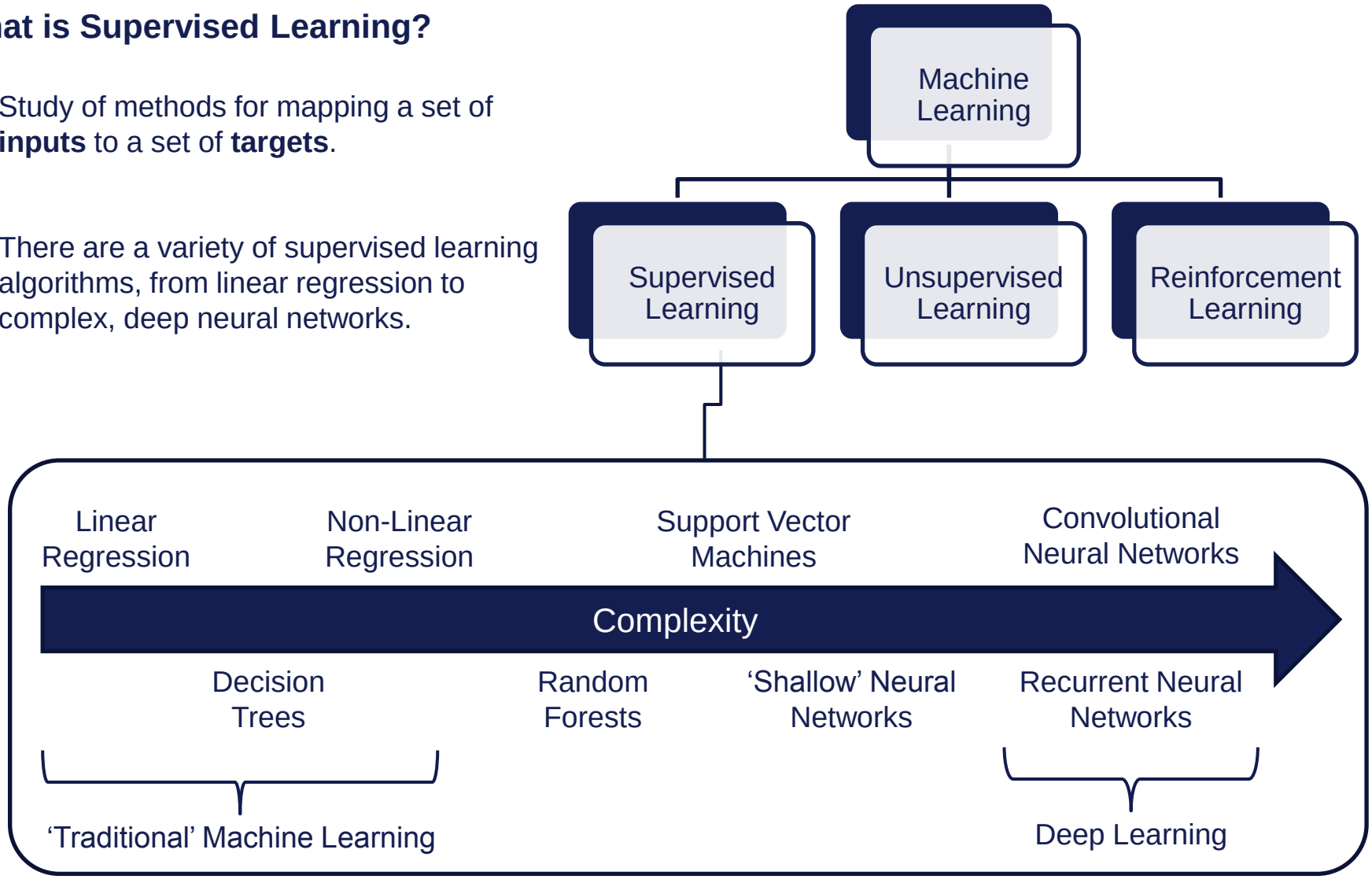
- Subfield of **Artificial Intelligence** focussed on the study of methods for **autonomously inferring relationships from data**.



Introduction to Machine Learning

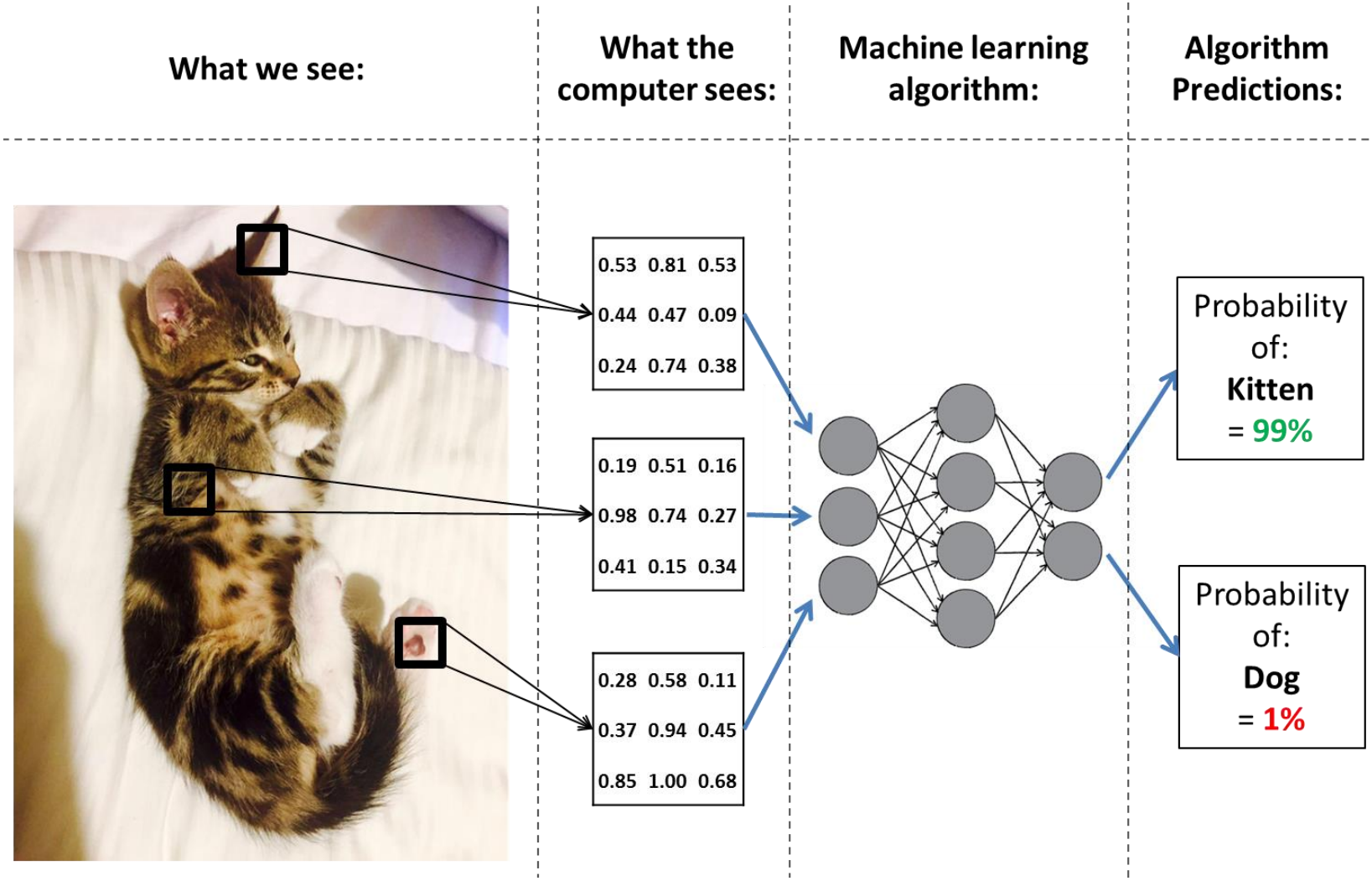
What is Supervised Learning?

- Study of methods for mapping a set of **inputs** to a set of **targets**.
- There are a variety of supervised learning algorithms, from linear regression to complex, deep neural networks.



Introduction to Machine Learning

Supervised Learning Example – Image Recognition



Source: Aberdeen Standard Investments, 27/09/2018

Introduction to Machine Learning

Why Machine Learning Now?

- A number of factors have developed over the past few years to catalyse the current AI/machine learning renaissance:

Big Data	• Data is the **fuel** of machine learning. • We are producing data at an unprecedented rate.
• Big data + machine learning => **HPC**. • Cloud Computing, GPUs, FPGAs, Database Solutions.	High Performance Computing (HPC)
Theoretical Innovations	• Landmark theoretical breakthroughs. • Backpropogation, **Deep Learning**, CNNs, RNNs.
• **MATLAB®,** Python, Scikit-learn, TensorFlow, Keras, R. • Academic Data Science, Coursera, Codecademy, Kaggle.	Proliferation of Software and Expertise

Source: Aberdeen Standard Investments, 27/09/2018

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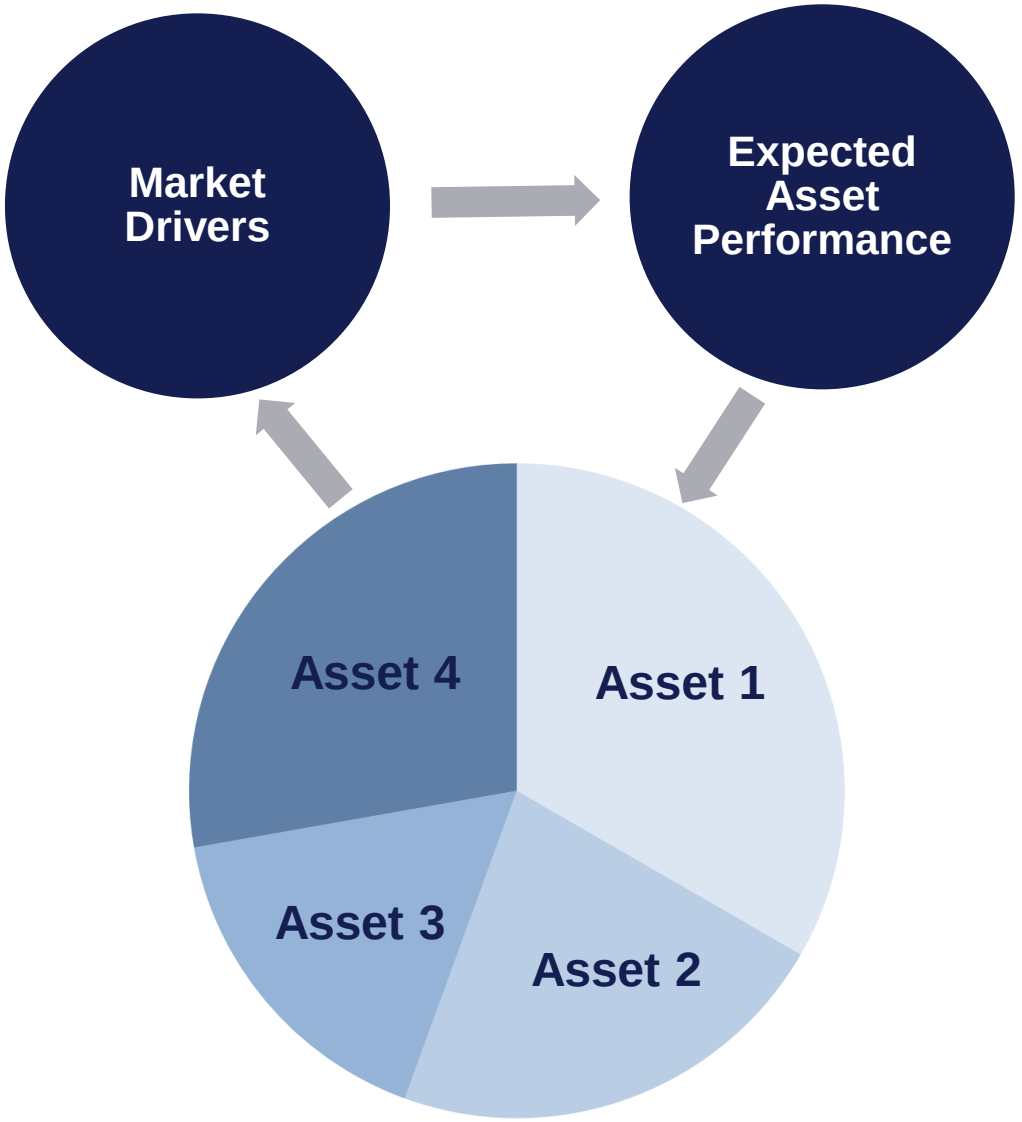
Machine Learning for Asset Allocation

Goal of Asset Allocation

- **Understand** the key drivers of market behaviour.
- **Predict** future asset performance.
- **Construct** portfolios based on expected behaviour to **deliver** desired investment outcomes.

Challenge

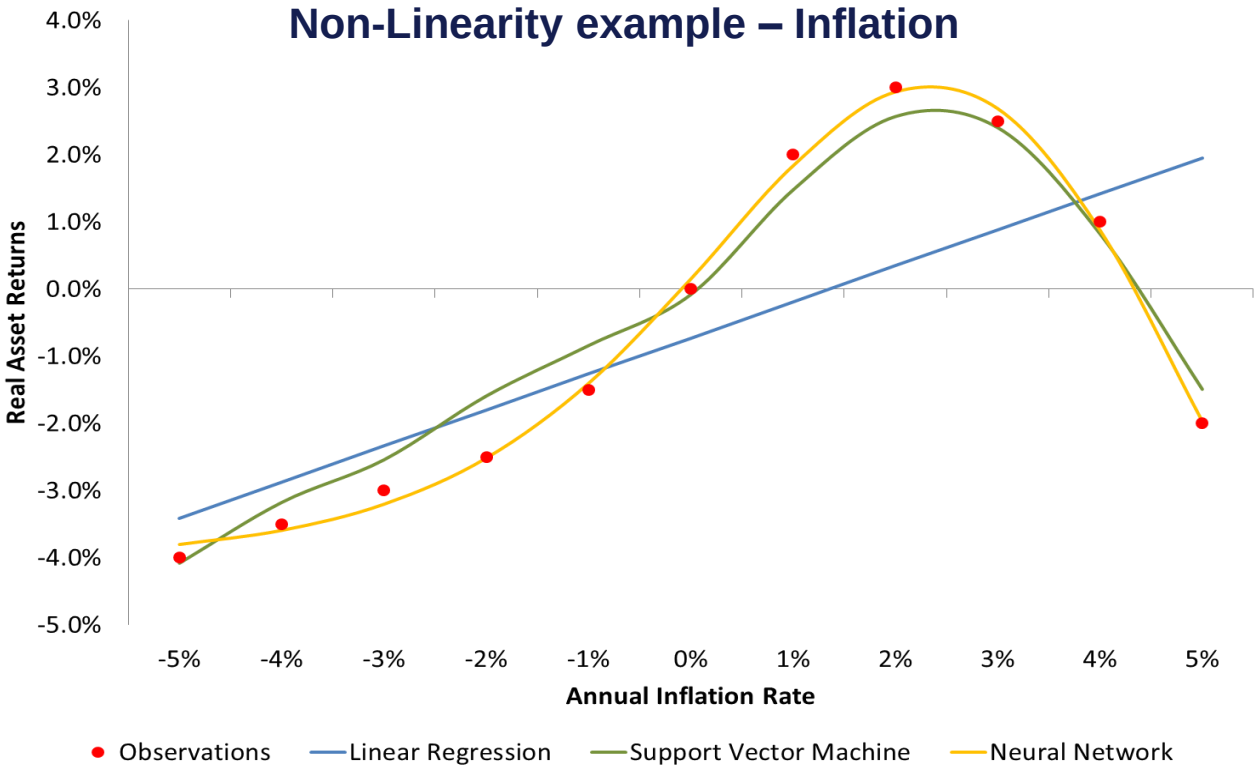
- Market behaviour is **complex**.
- Driven by **multi-dimensional**, **non-linear** relationships.



Machine Learning for Asset Allocation

Why Machine Learning In Investment?

- Asset prices are driven by a multitude of factors, from **macroeconomic** conditions and investor **sentiment**, to the whims of day traders or **unpredictable** geopolitical events.
- The result is that relationships in financial markets are highly **multi-dimensional** and **non-linear**, requiring suitably complex modelling approaches to understand such dynamics.



Data is hypothetical and for illustration purposes only.

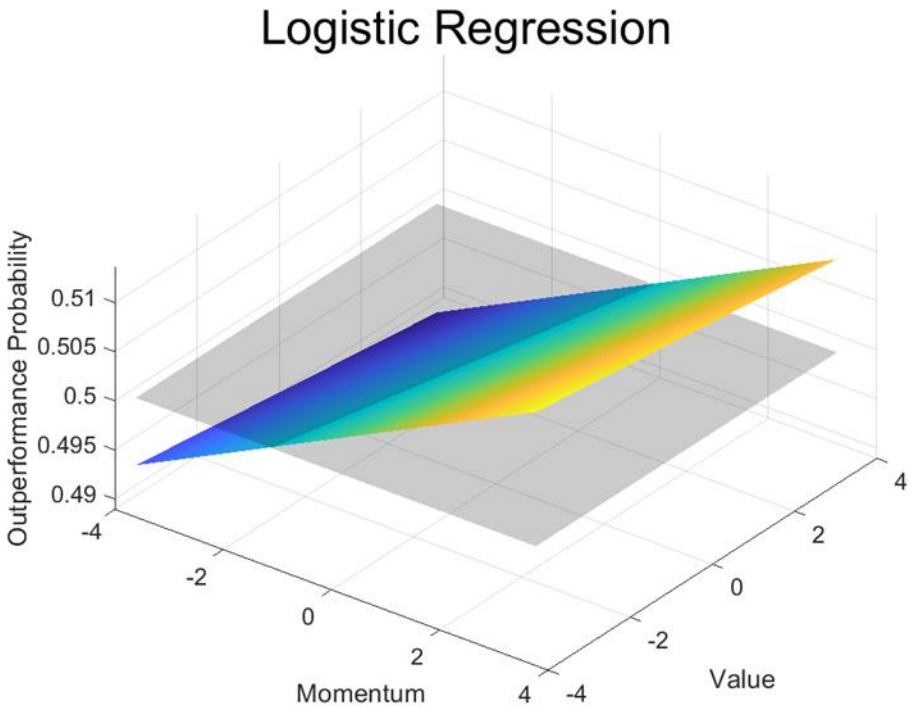
Source: Aberdeen Standard Investments, 27/09/2018

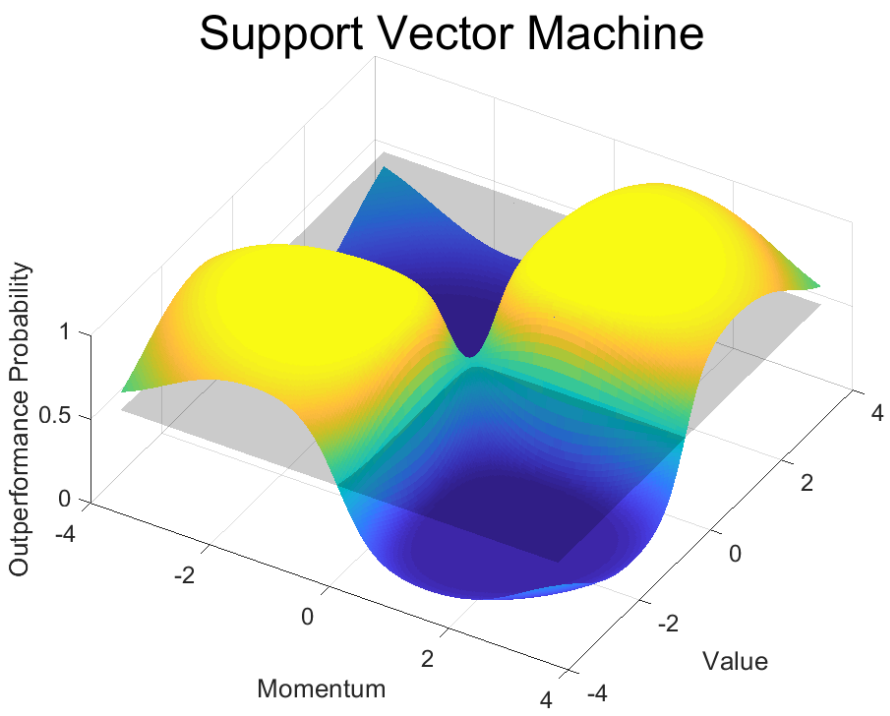
Machine Learning for Asset Allocation

Multi-Dimensionality

- Relationships may also be non-linear *and* multi-dimensional, for example a typical XNOR type relationship between asset price performance and two hypothetical factors ‘Momentum’ and ‘Value’.

- Again, we may be able to model such dynamics with traditional models using interaction terms, however this is a manual process and very difficult in higher dimensions.





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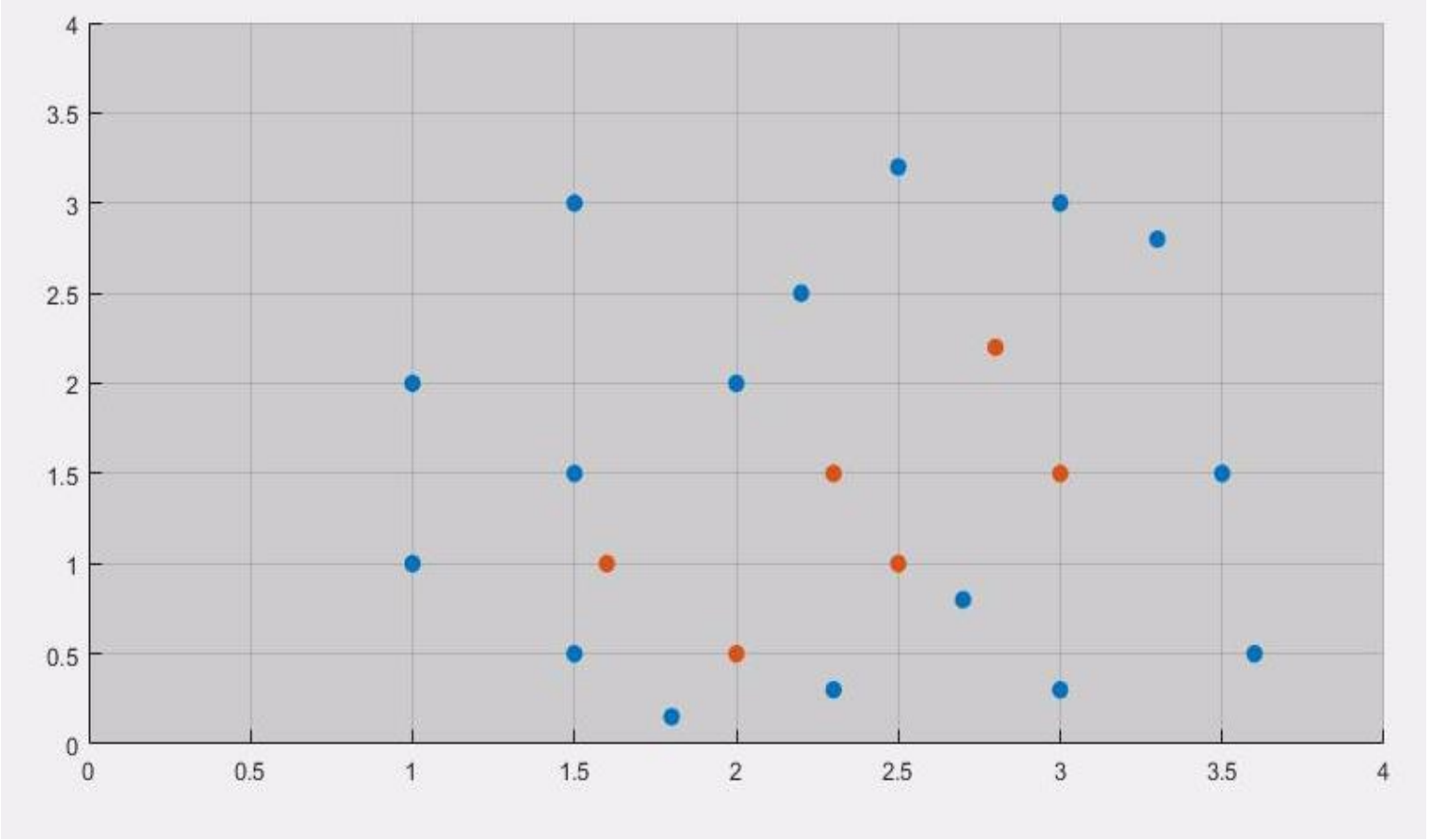
Machine Learning for Asset Allocation

How does it work? – Support Vector Machines

- Non-linearly separable classes are separated by automatic space transformations.



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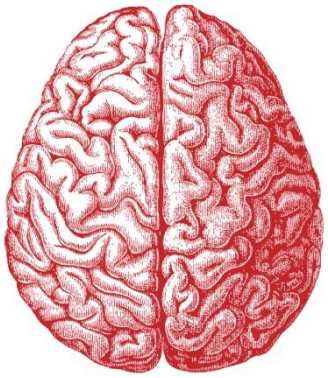
Machine Learning for Asset Allocation

Key Advantages

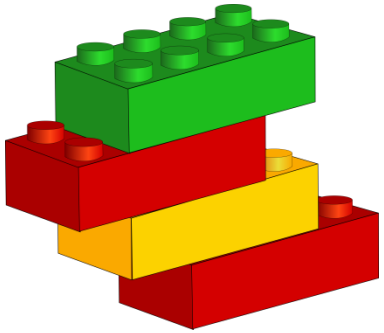
- State of the art learning methods
- Can be tailored to individual investment needs
- Scalable to new asset classes or strategies
- Uncorrelated with other investment approaches

Intelligence

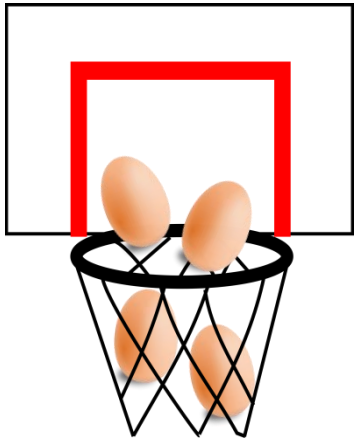


Flexibility

Scalability



Diversification



Machine Learning for Asset Allocation

Market factors definition

- Macroeconomic
- Value
- Liquidity
- Sentiment

Leveraging industry and academic research for factor pre-selection

Machine learning input

Data cleansing, signal processing and transformation in order to define the input to the Machine Learning algorithms

Data transformation for interpretability

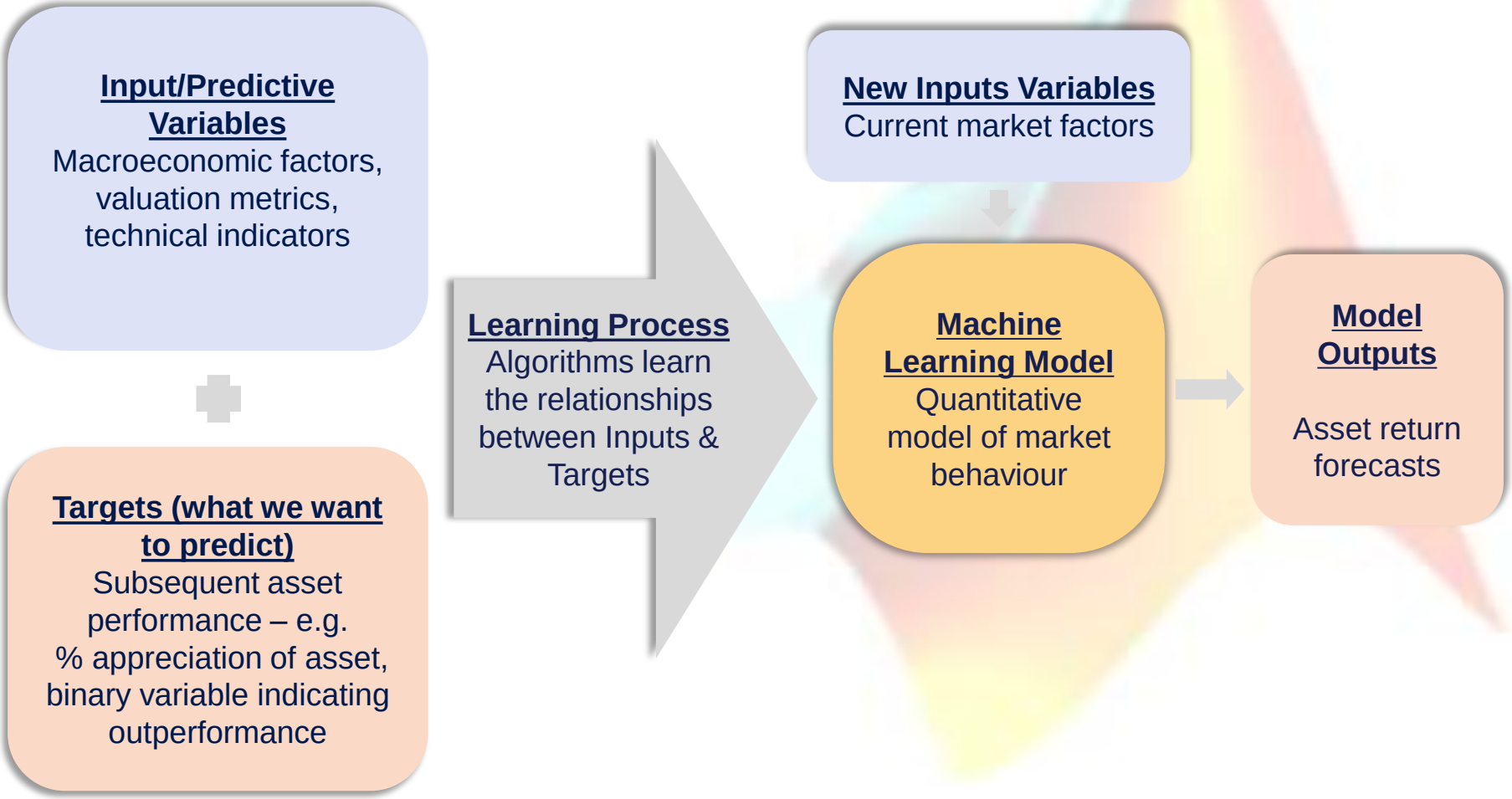
Question to the machine

- Tactical Asset Allocation: underweight Credit to overweight Equities
- Absolute Return: Short FTSE 100 **vs** Long S&P 500
- Ability to accommodate different risk and target return client profiles

Defining the problem

Machine Learning for Asset Allocation

Supervised Learning for Asset Allocation



Machine Learning for Asset Allocation

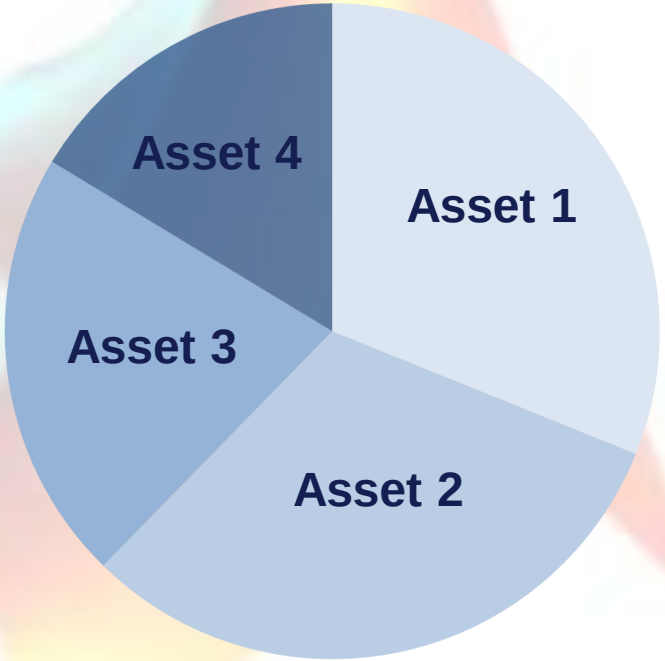
Model Outputs used for Portfolio Construction

New Inputs Variables
Current market factors

Machine Learning Model
Quantitative model of market behaviour

Model Outputs

Asset return forecasts



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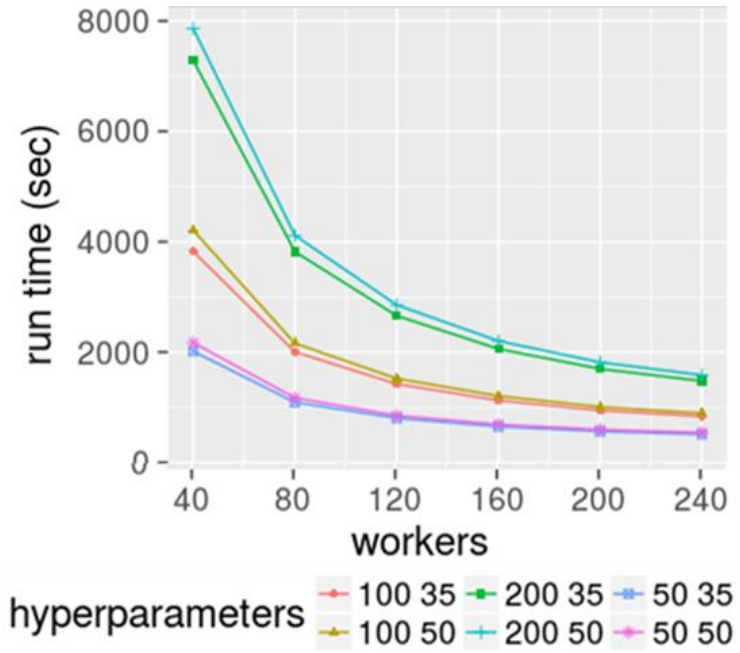
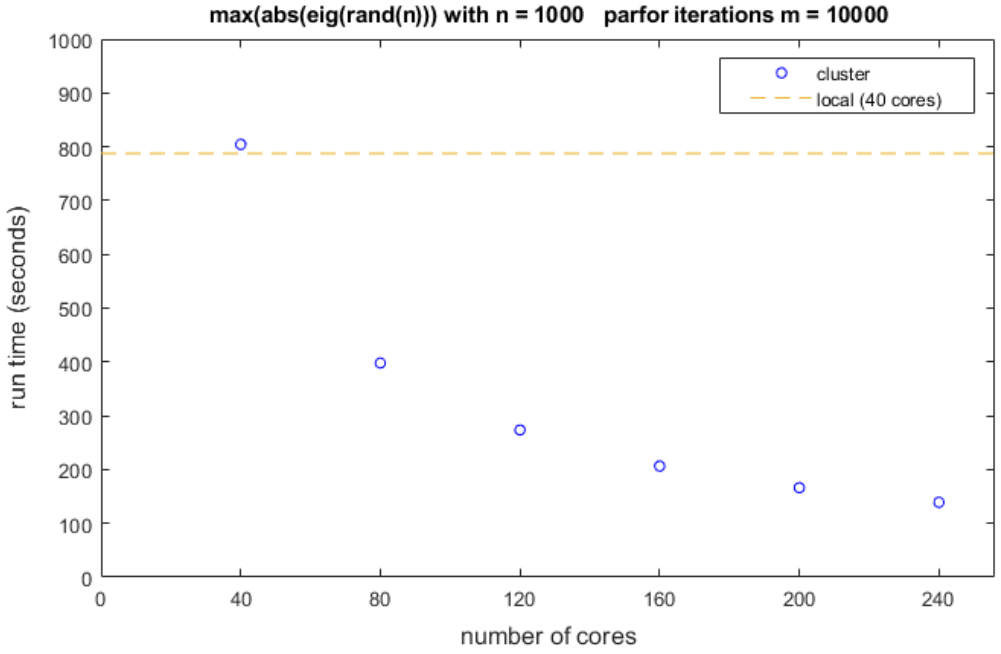
Macro Machine Learning with MATLAB®

HPC - Distributed Computing Cluster with MATLAB®

- Academic collaborations have produced various papers on accelerating our investment process with HPC.
- 2018 paper "*Parallelising a Machine Learning Application in Computational Finance*" explored using the MATLAB® Distributed Computing Cluster.



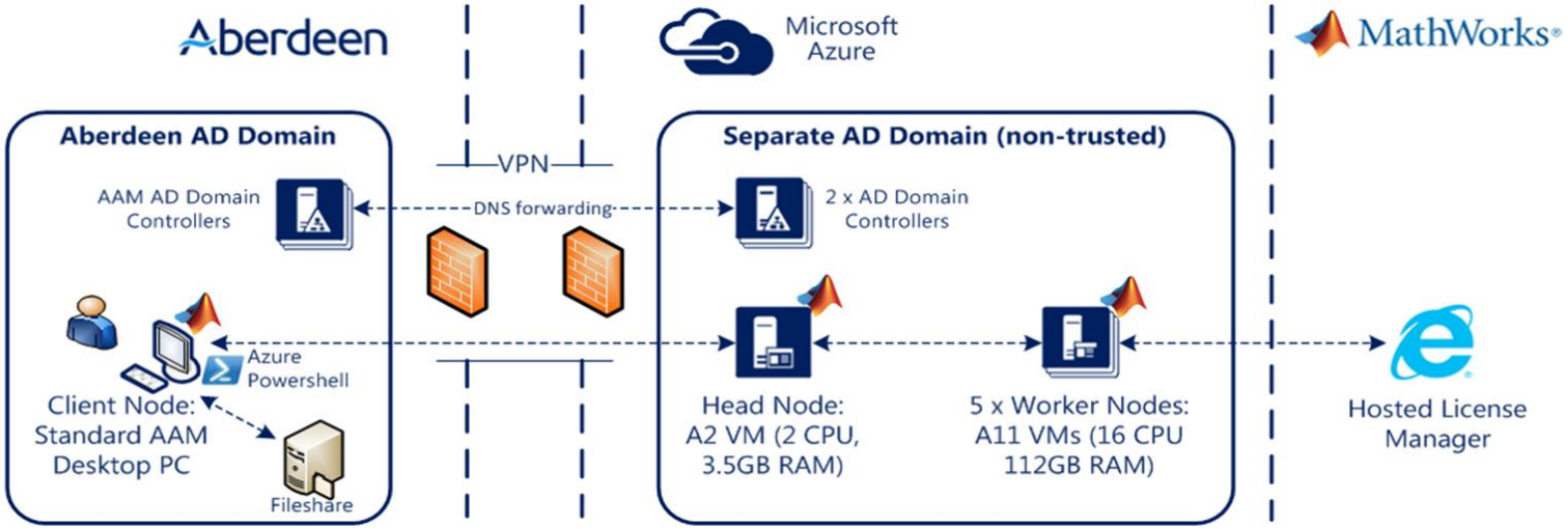


- The study achieved near-linear speed improvements using the distributed cluster, enhancing the scope of our research and testing capabilities.

Source: Aberdeen Standard Investments, 27/09/2018

Macro Machine Learning with MATLAB®

HPC - Cloud Computing and Distributed Computing Server



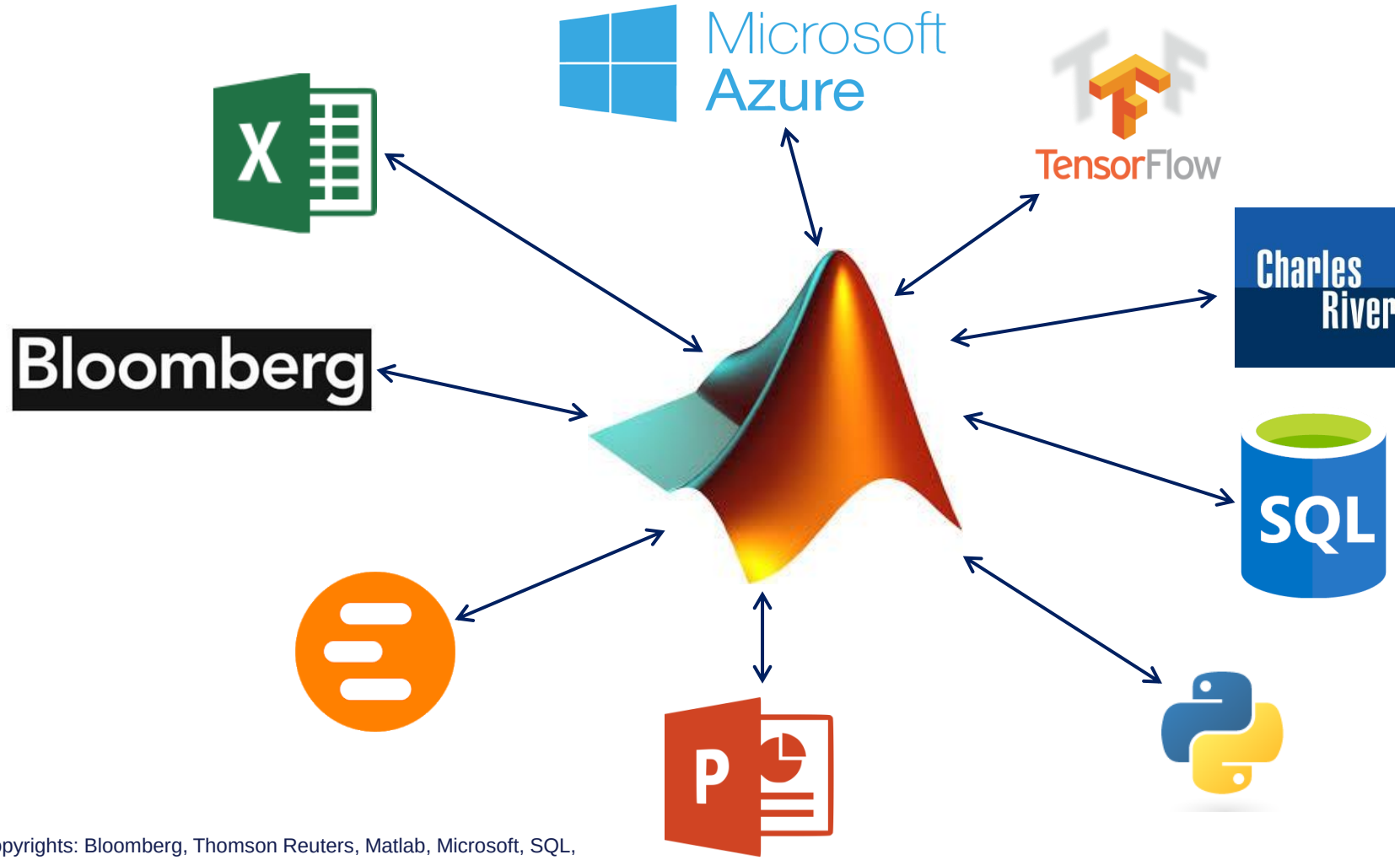
Key Points:-

- The Head and Worker Node Virtual Machines (VMs) are started when the cluster is required and stopped once no longer needed. This is done by the users using bespoke, in-house built Powershell scripts. The MDCS Windows Service (mdce) is auto-started on each VM and the cluster comes up in a handful of minutes
- Fixed IP addressing used for VMs to ensure cluster comes up cleanly every time
- No data is stored in Azure. Data passes from the Client Node to the Worker Nodes via the Head Node

Source: Aberdeen Standard Investments, 27/09/2018

Macro Machine Learning with MATLAB®

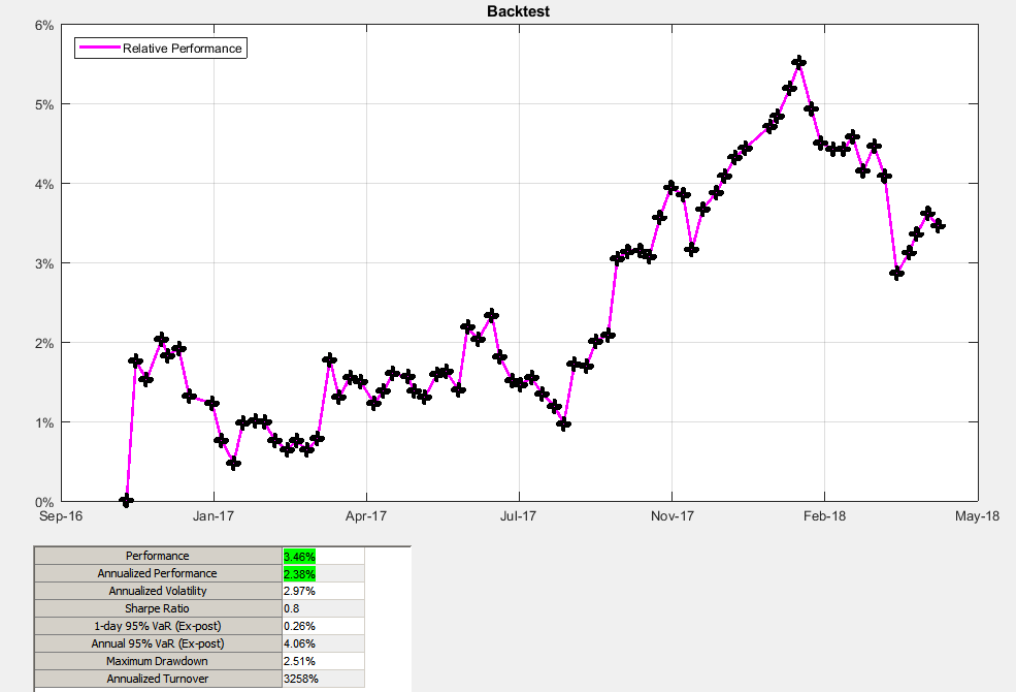
Deep integration with other key systems



Macro Machine Learning with MATLAB®

MATLAB® App Designer

- Purpose built apps for regular tasks ensure the process is scalable and robust –
  - **Strategy backtesting**
  - **Portfolio Management**
  - **Trade Execution**
  - **Live Performance Monitoring**
  - **Auto-Generated Reports**



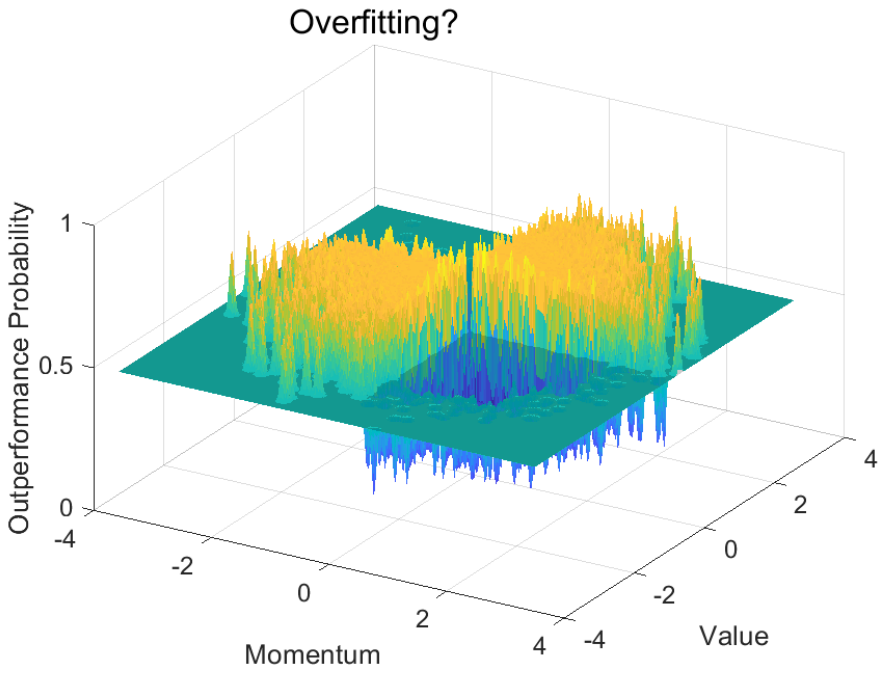
Performance	3.46%
Annualized Performance	2.38%
Annualized Volatility	2.97%
Sharpe Ratio	0.8
1-day 95% VaR (Ex-post)	0.26%
Annual 95% VaR (Ex-post)	4.06%
Maximum Drawdown	2.51%
Annualized Turnover	3258%

Performance numbers are hypothetical and for illustration purposes only.

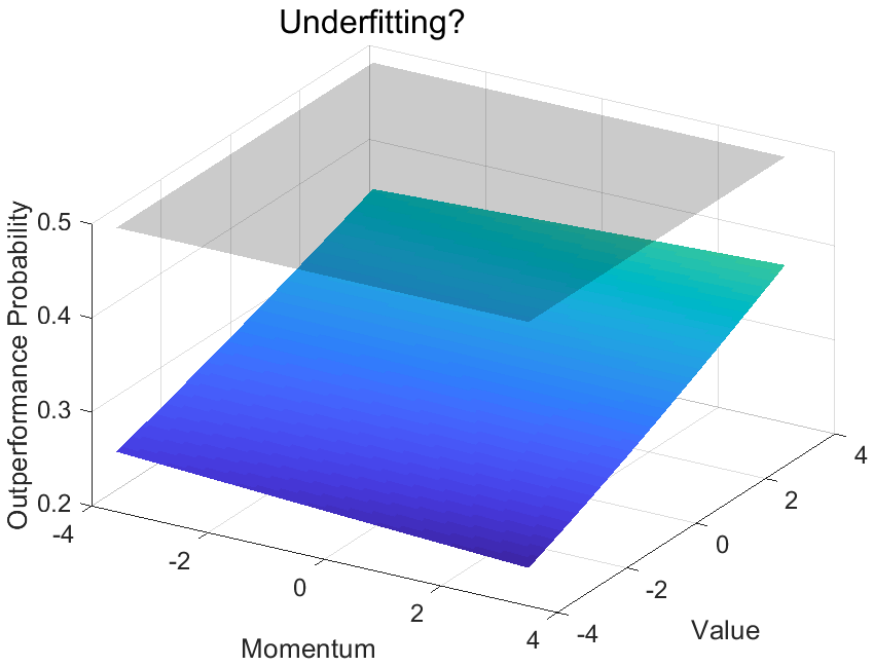
Source: Aberdeen Standard Investments, 27/09/2018

Macro Machine Learning with MATLAB®

Model Interpretation and Visualisation – Feature Sensitivity Analysis



- Model **interpretability** is a key problem in machine learning.
- Looking under the hood of an algorithm is key to understanding whether a model is behaving properly.



- Our purpose built **Feature Sensitivity Analysis** capability uses MATLAB® **visualisation** tools to improve model explainability.

Data is hypothetical and for illustration purposes only.

Source: Aberdeen Standard Investments, 27/09/2018

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