Machine learning algorithms for mineral processing

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Introduction to MIDAS Tech

- Dr Stephen Gay was a researcher at *JKMRC* (UQ Mineral Research Centre) developing mathematical models
- Started business (*MathsMet*) 2011 – mainly to focus on contract work
- Developed independent software in gaps between contracts
- In 2013 Govt. incentives encouraged commercialisation.
- Initiated patent 2014 (to be briefly explained); formed *MIDAS Tech* primarily with goal of seeking investors

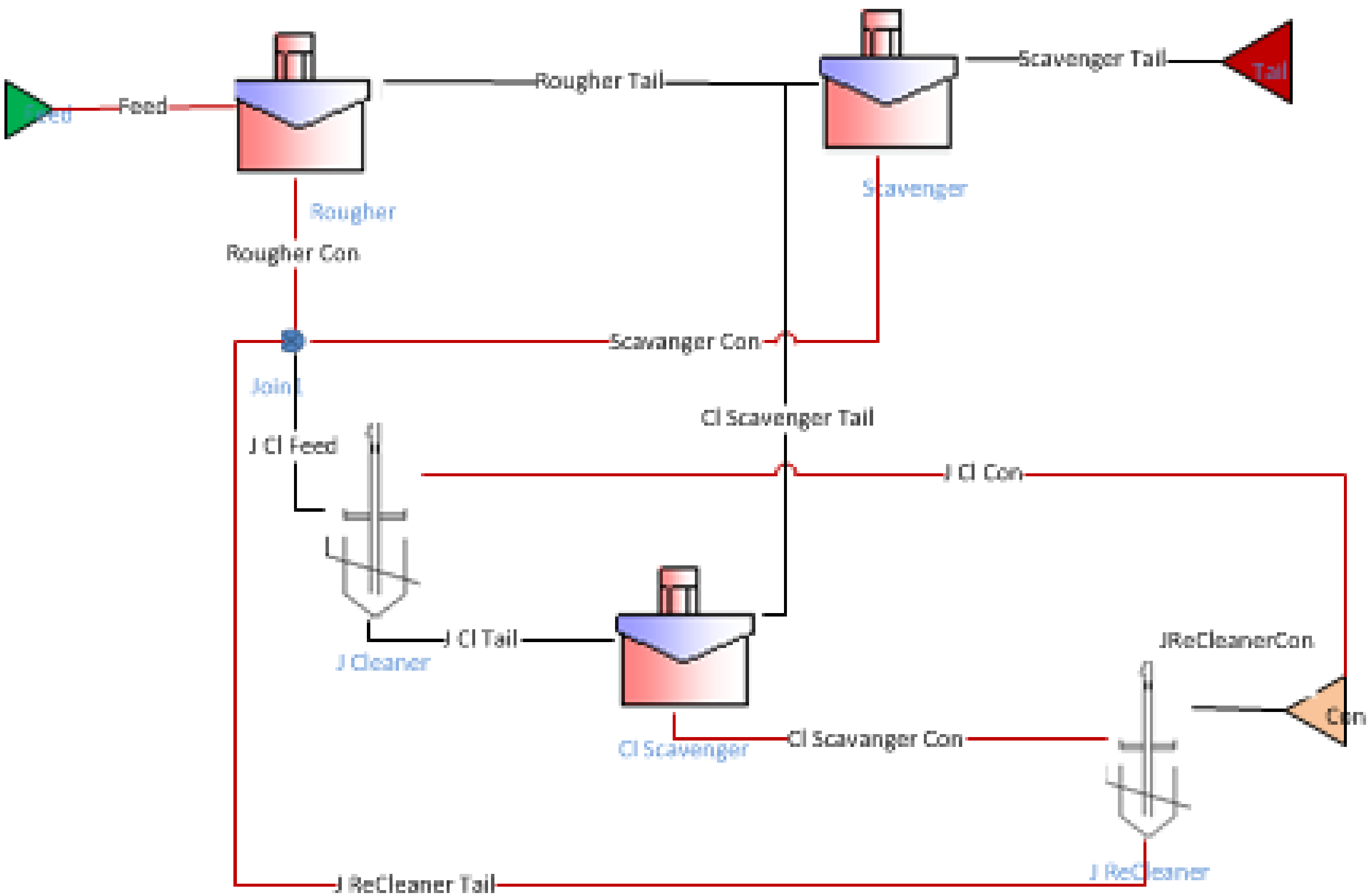
MIDAS Tech current activities

- Promotion of mineral processing software
- Development of General Excel flowsheet simulation (or process modelling) system (*MMXLSim*)
- Development of numerous addins for *Structured Efficient use of Excel* (*SEES*)
- Courses and Training in these activities.

Objectives of mineral processing software

- Provide an advanced and intelligent method to analyse plant data to:
  - Understand current performance
  - Identify operational changes required to improve plant performance.

Overview of mineral processing



Current conventional optimisation approaches

- Requires extensive surveys
- Time consuming
- Often not practically viable.
- Expensive

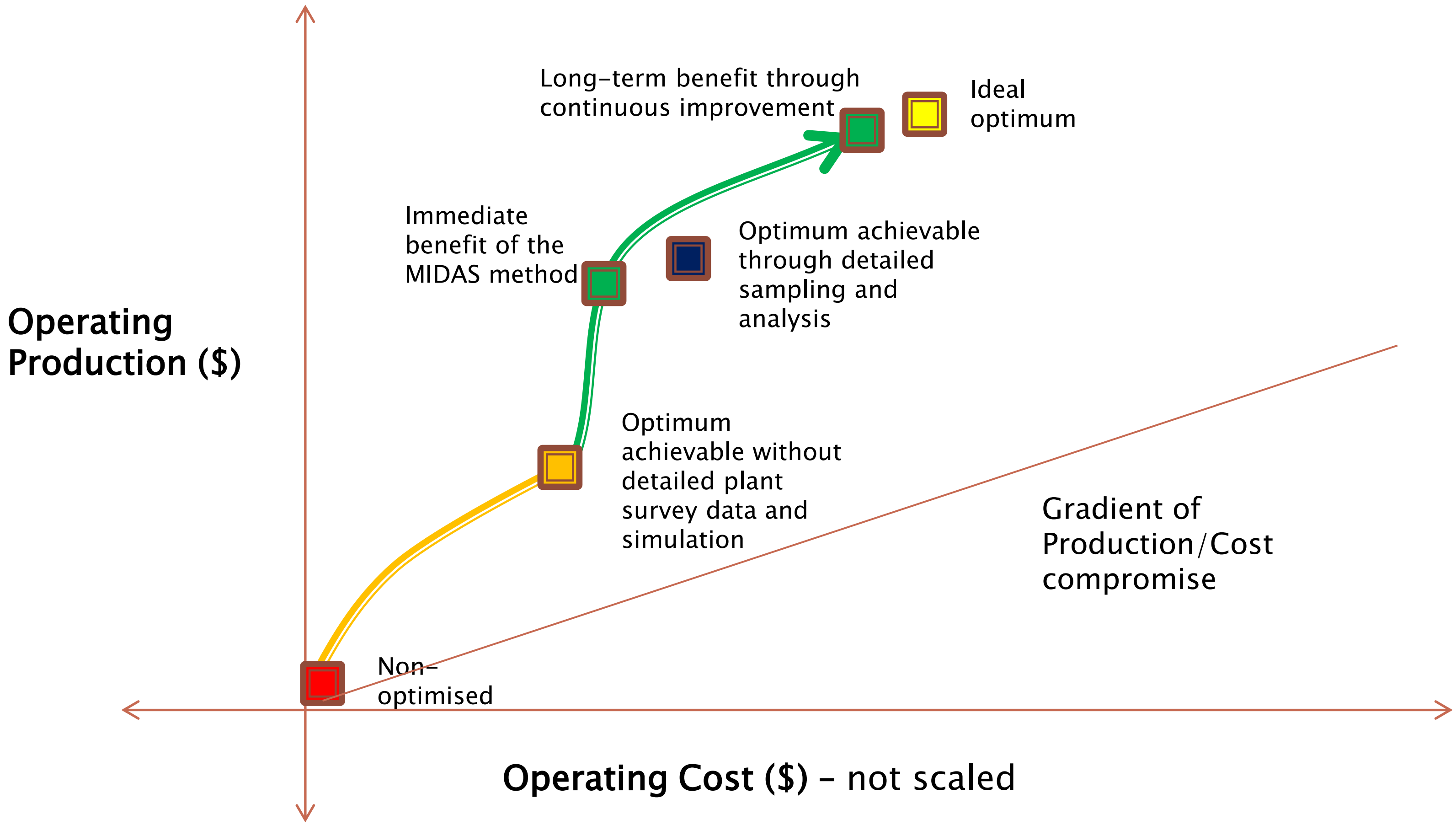
Circuit surveys are rare

Overcoming the pain points

A method is required that:

- Uses available data without requiring costly plant surveys.
- Makes use of practical mathematical methods
- Methods accessible by user-friendly software

Proposed approach

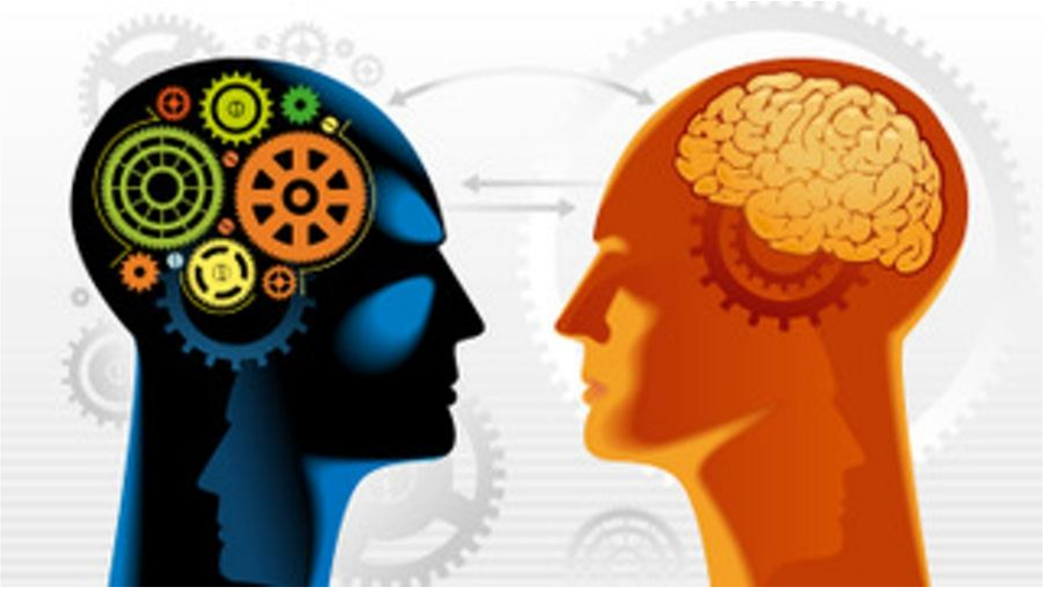


Nine steps for optimising a mineral processing plant

1. Collect data (3 hours)
2. Collate data (1 day)
3. Construct the flowsheet (3 hours)
4. Mass Balance (3 hours)
5. Infer missing data (1 day)
6. Define operational variables (1 day)
7. Modelfit (1 day)
8. Simulate (1 day)
9. Optimise (3 hours)

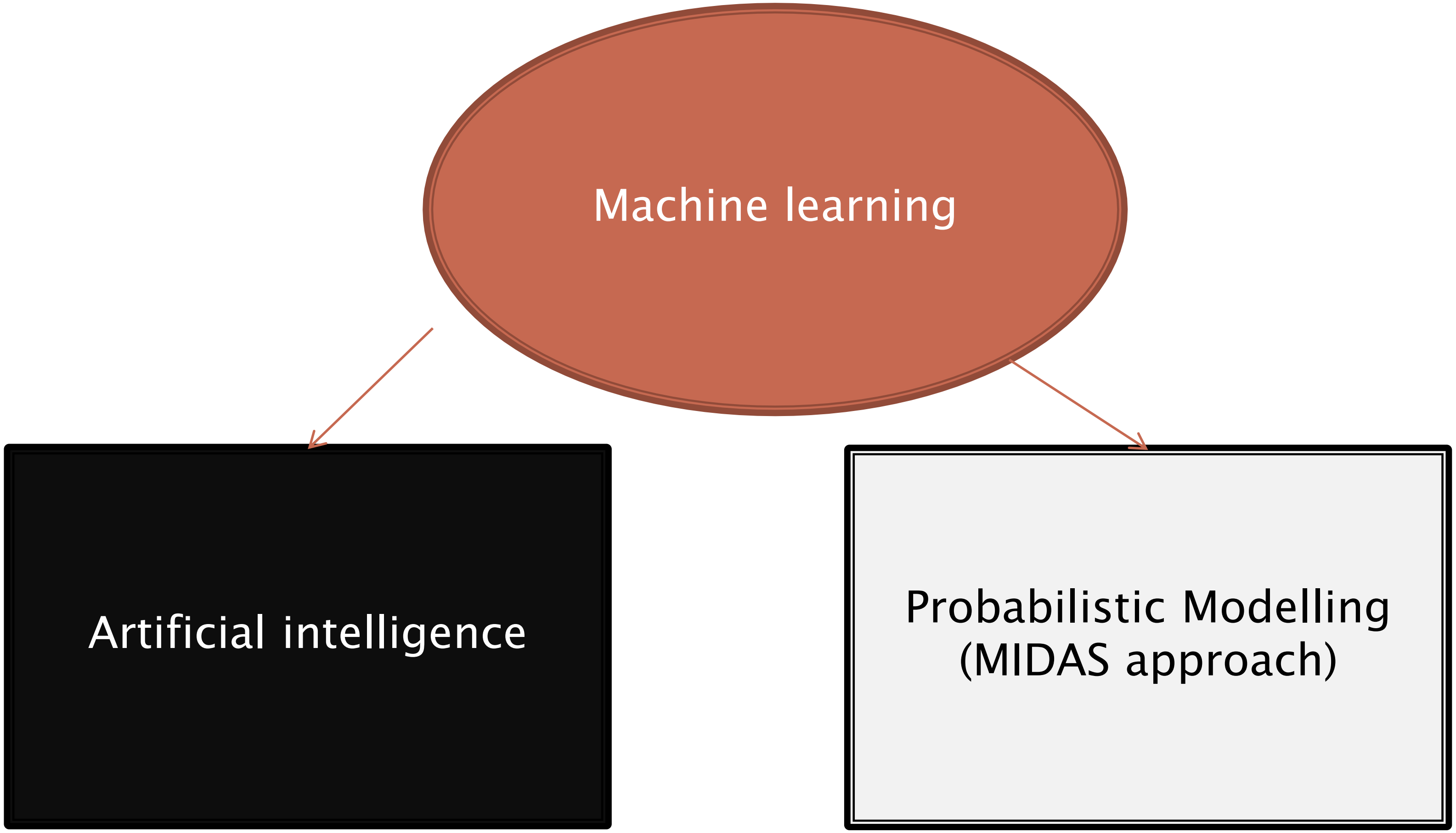
What is machine learning?

"Machine learning explores the study and construction of algorithms that can learn from and make predictions on data."



Source: Coursera

Machine learning



AI – 9 steps reduces to 5

1. Collect data
2. Collate data
3. ~~Construct the flowsheet~~
4. ~~Mass Balance~~
5. ~~Infer missing data~~
6. Define operational variables
7. Modelfit
8. ~~Simulate~~
9. Optimise

MIDAS method to 9 steps

1. Collect data (C – Conventional)
2. Collate data (Database algorithms)
3. Construct the flowsheet (Visio)
4. Mass Balance (IT – Information Theory)
5. Infer missing data (IT)
6. Define operational variables (ML – Machine Learning)
7. Modelfit (ML)
8. Simulate (C)
9. Optimise (Advanced optimisation algorithms)

MIDAS Method

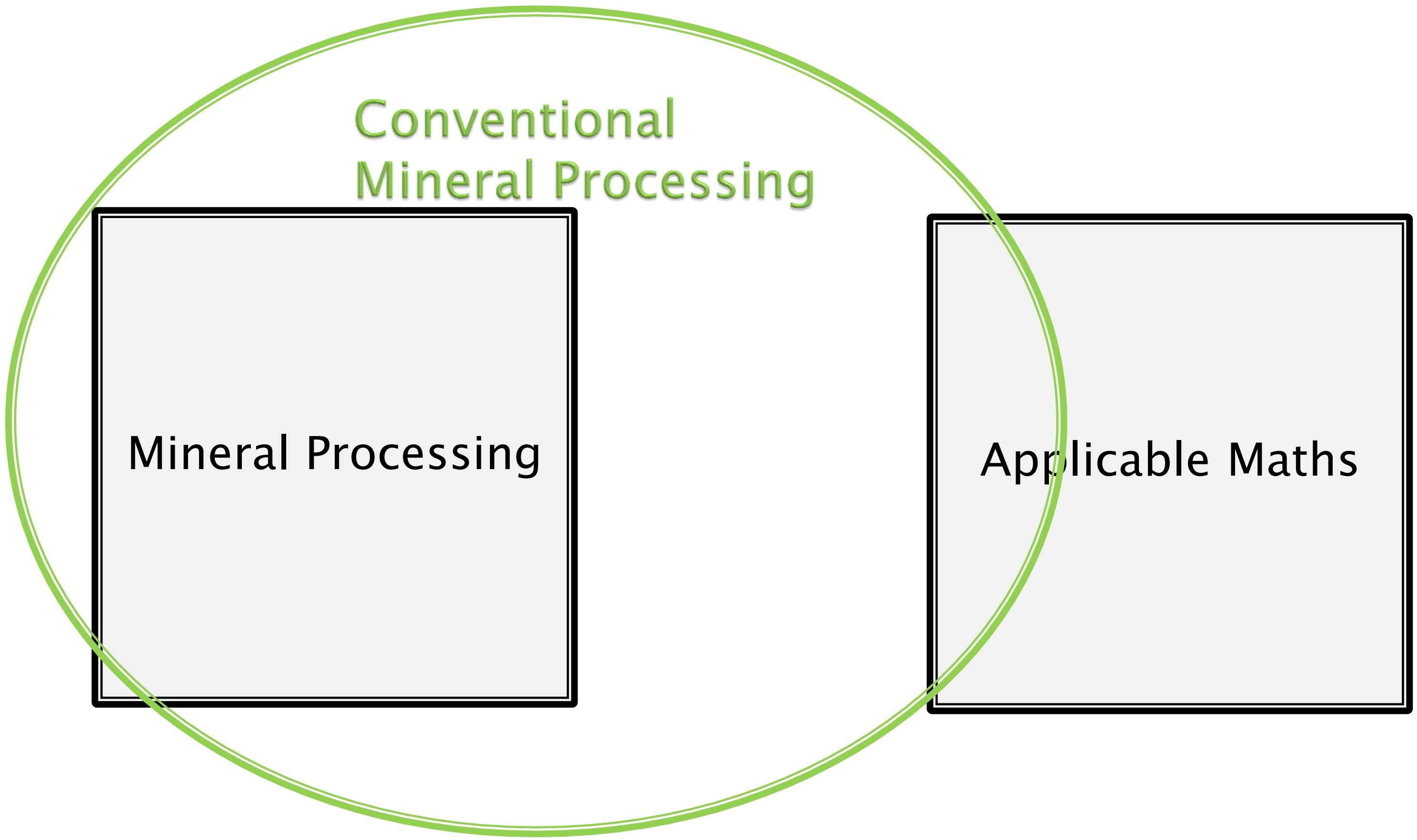
Strengths

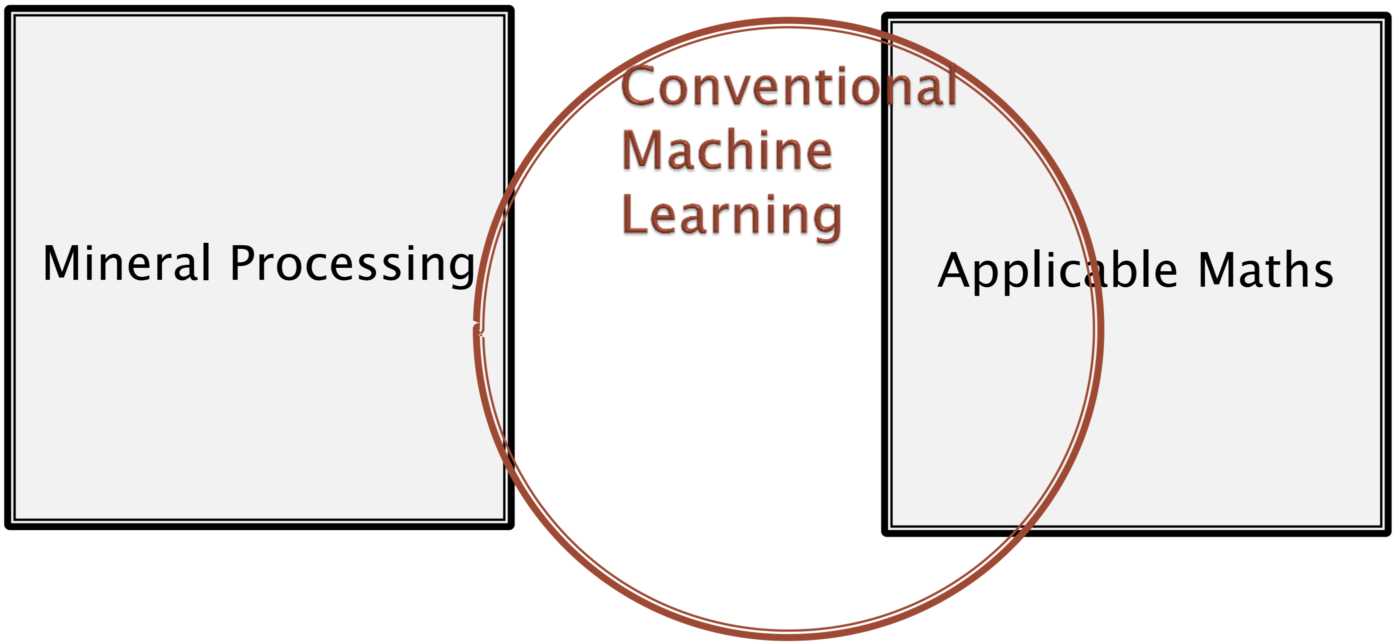
- Uses all nine steps
- Strong basis in classical maths (starting with Bayes; now most relevant subbranch is information theory)
- Requires structured use of data
- Requires a mathematical modeller
- Can be linked to domain knowledge.
- Provides results that are physically meaningful.

Business scope

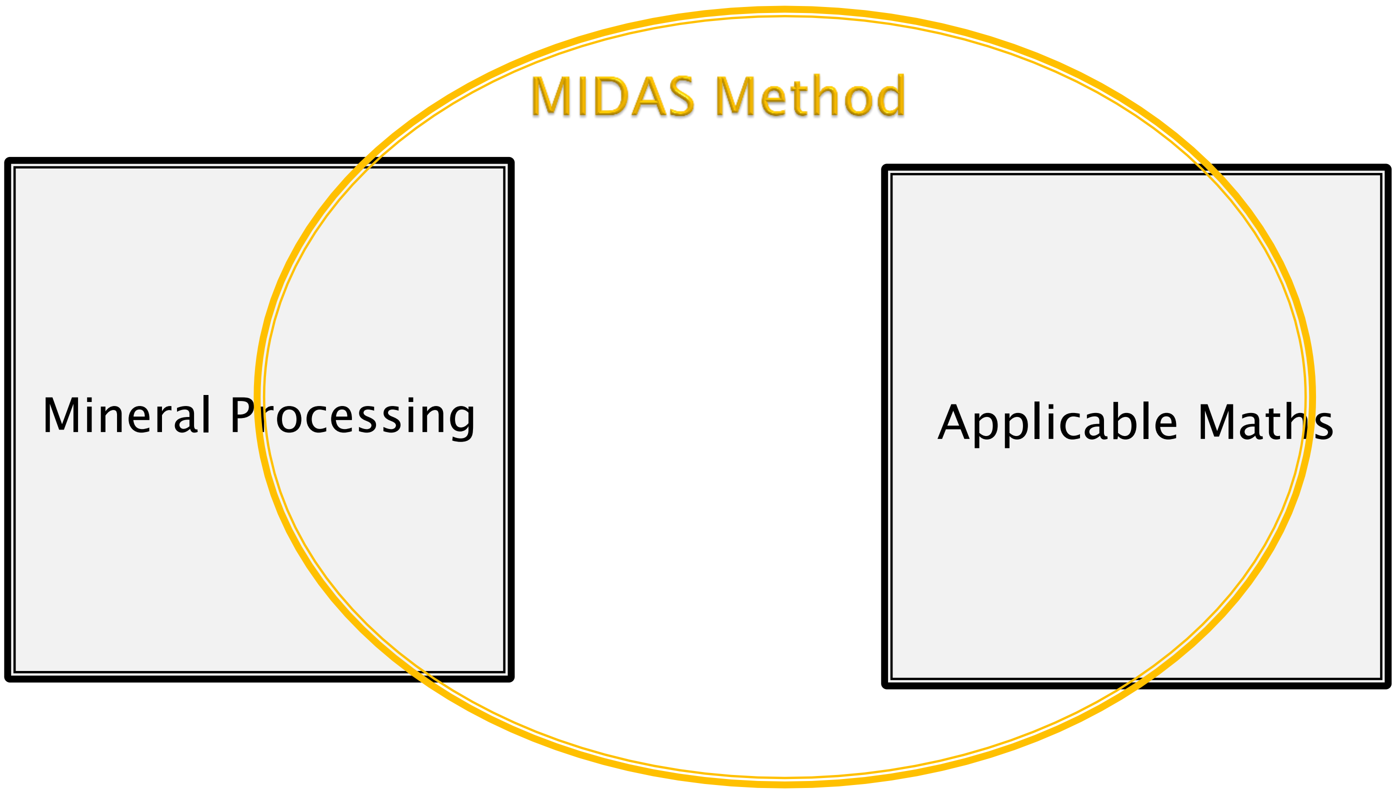
Mineral Processing

Applicable Maths


Conventional
Mineral Processing
Mineral Processing
Applicable Maths

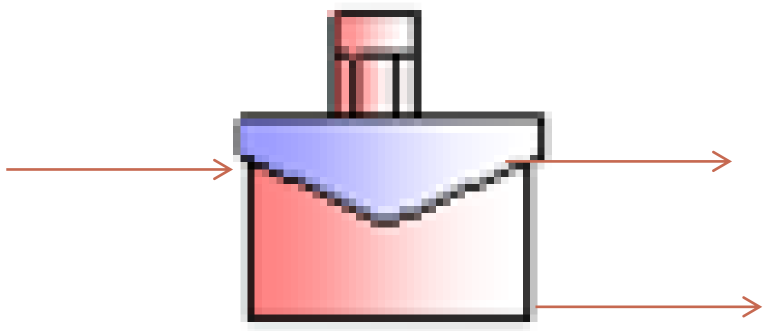


Mineral Processing
Conventional Machine Learning
Applicable Maths


MIDAS Method
Mineral Processing
Applicable Maths

The core issue – Inference

Mineral processing consists of numerous units i.e. flotation cell

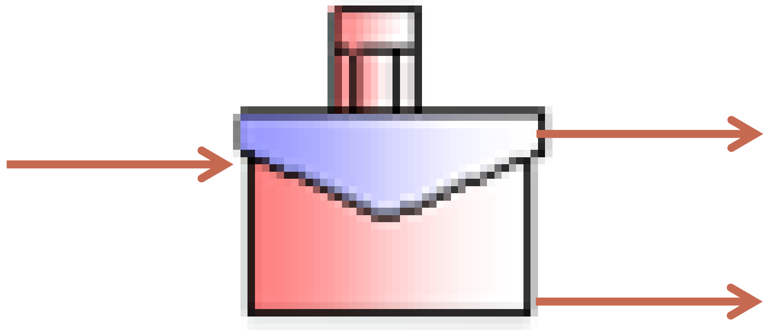


How to construct models:

- Phenomenological (valid to a point)
- Empirical (hardly a model) – often ends up with minimum 3 year PhD project
- Data-driven (Requires detailed ore properties)

Mass Balancing

- Stream information is adjusted or calculated using least squares minimisation



Mass Balancing can also be determined by information theory

- Very little research on comparison
- Information theory does not require standard deviations (which are generally unknown)
- Information theory allows inference (regularisation) of missing variables.

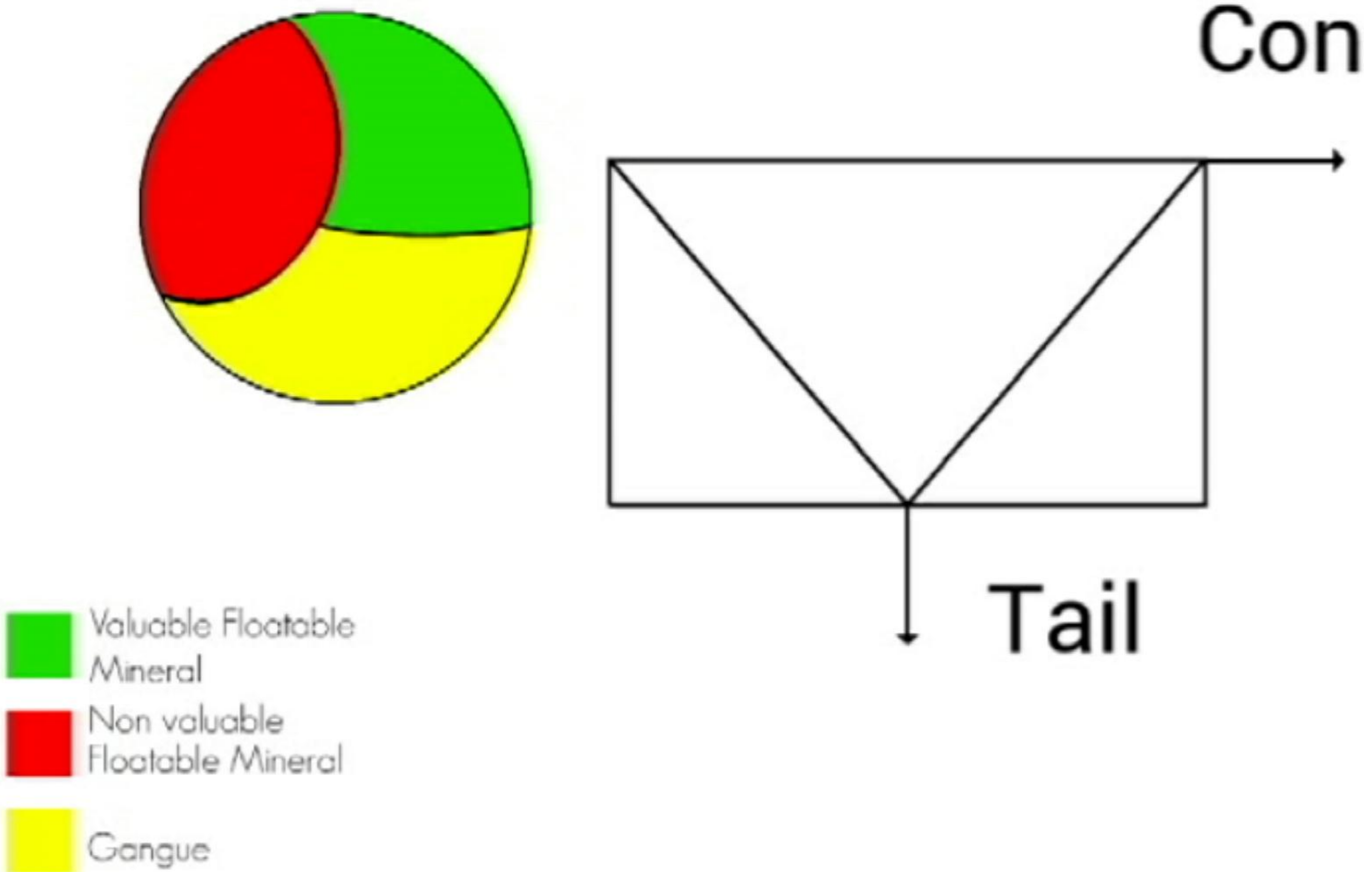
Multi- mineral particles

- Multi-mineral particles generally considered ‘too difficult’, so datastructures are simplified.
- Fantastic approach if ore conforms to the simplifications – but they don’t.
- Huge (megaMillions) of funding goes to developing flawed model approaches.

Information theory

- Estimation of microscale data from megascale data. Uses probability entropy.
- A particle has a probability of going to the con. or the tail.
- So treat a mineral processing system as a probability network.
- Adjust probabilities to satisfy information.

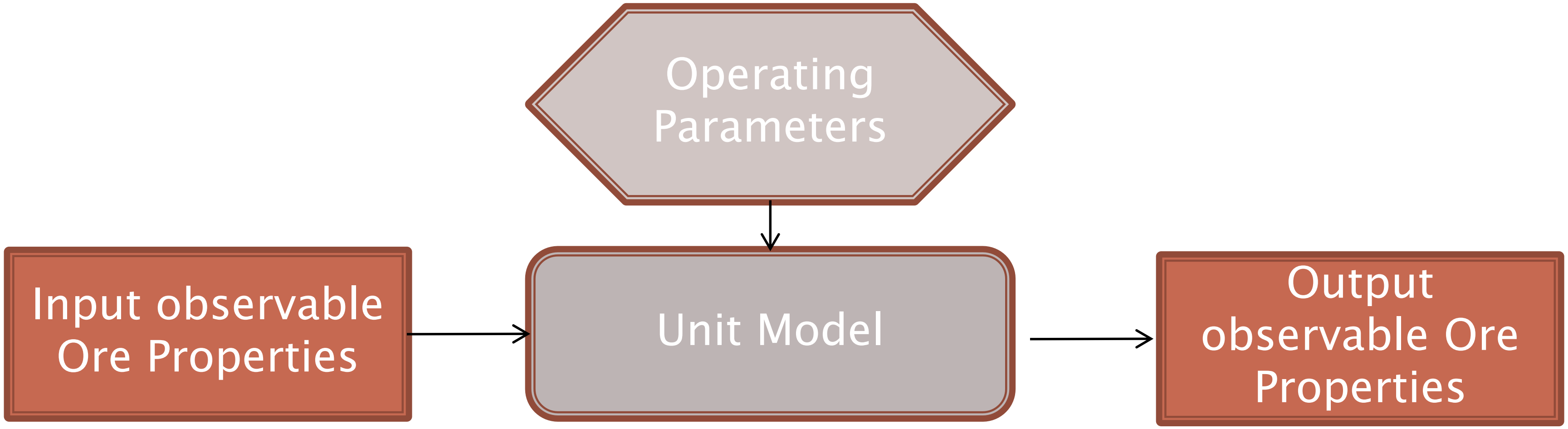
Process modelling as probability modelling



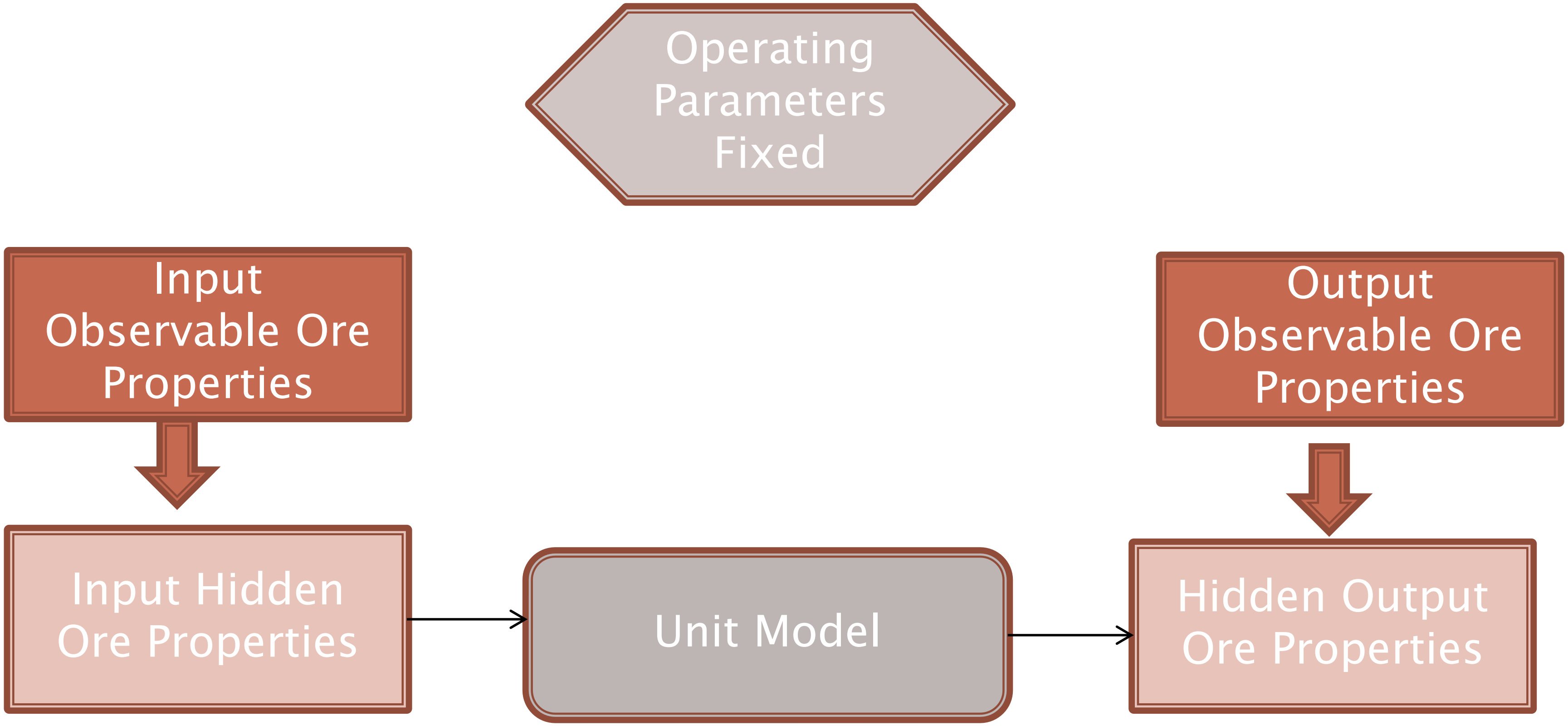
Patented approach

- Use ore variability to advantage
- If there has been no operational change to a unit then the unit processes the ore with the same model.

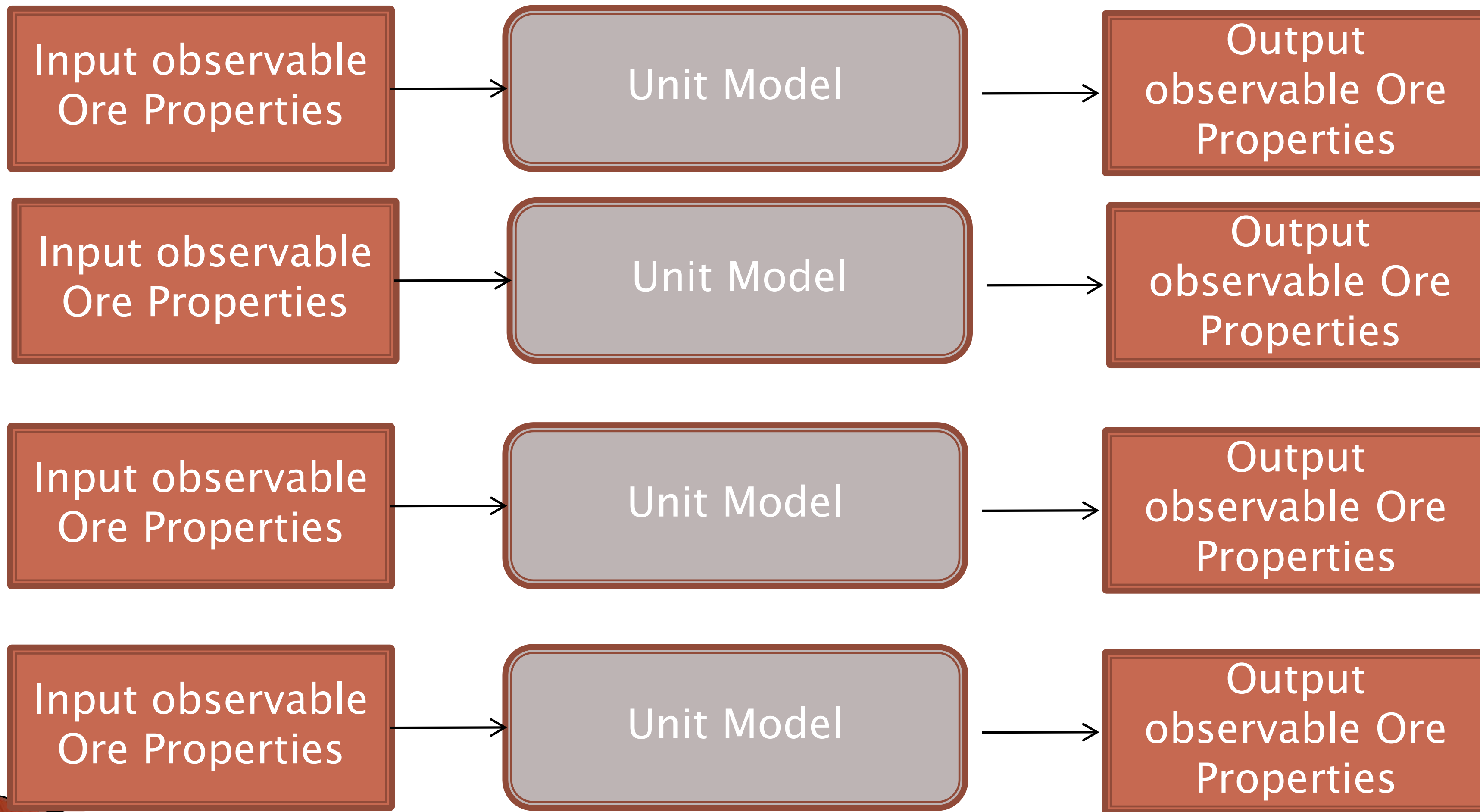
Traditional Modelling



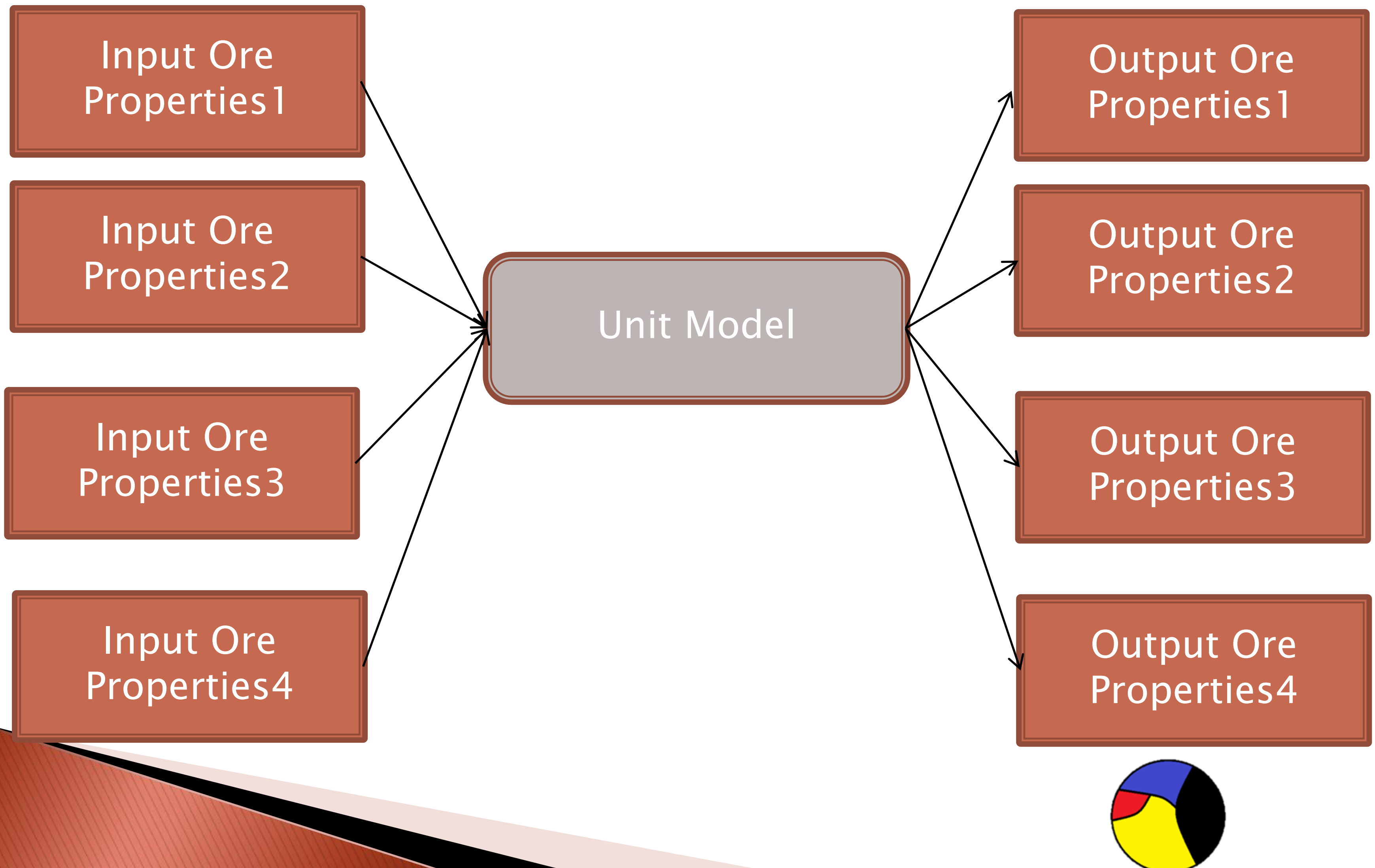
Advanced Modelling



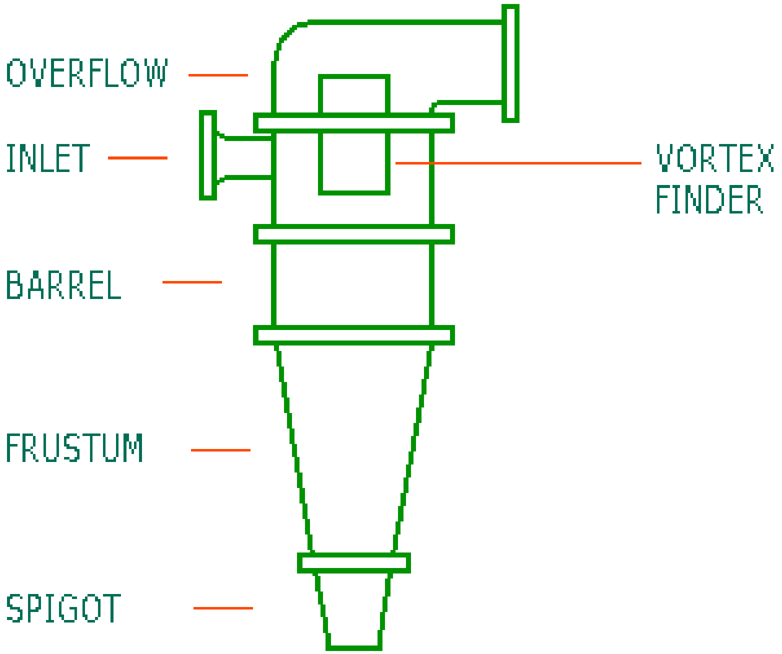
Change to Modelling (traditional)



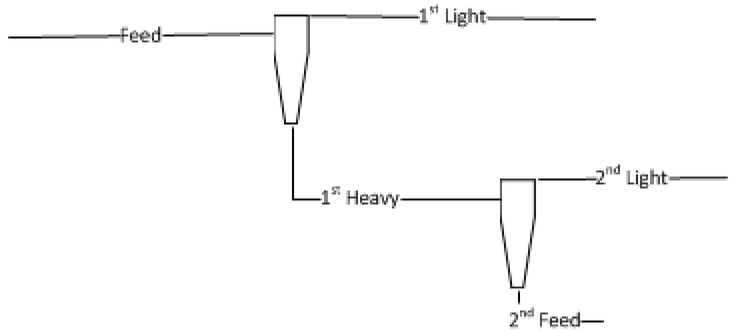
Advanced – concept of ‘similarity’



Cyclone example

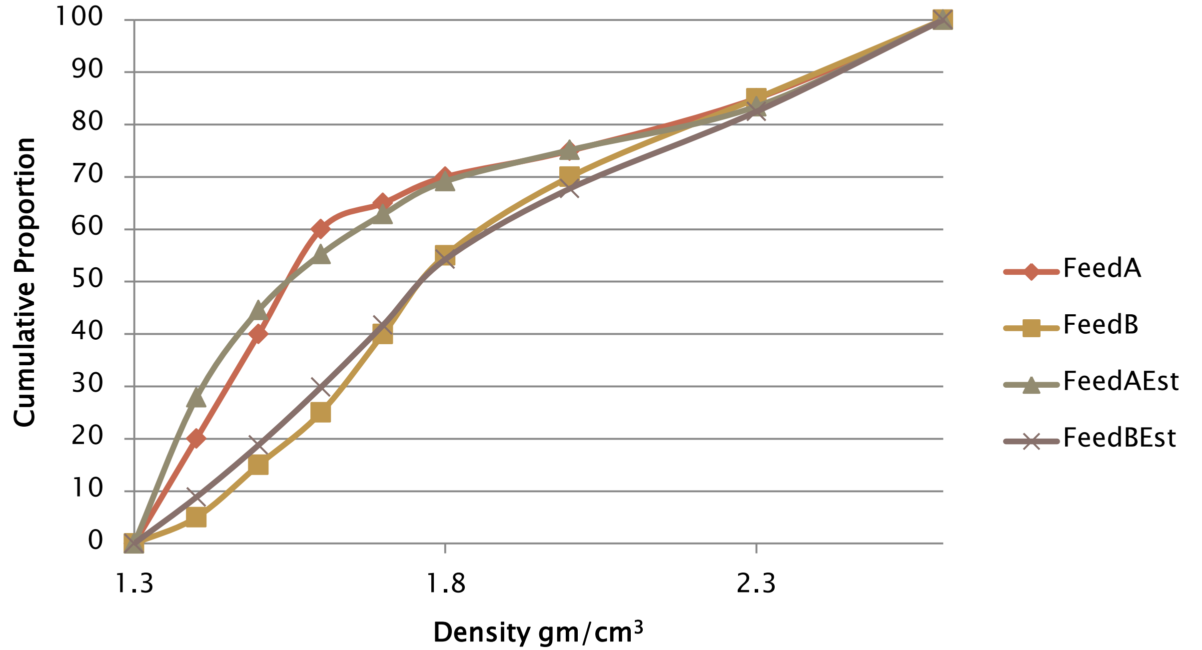


Two cyclones in series



A practical example – Case II

Back –calculation of washability curves



New method vs. standard method

- New method (for two units) requires only average density (for each size) of products.
  - Less sampling
  - Less laboratory tests (quicker)
  - Uses available data
- Conventional method requires float-sink on feed and two products.
  - More samples
  - More laboratory tests (Slower)

Extension of inference to machine learning

- By using inference one can construct ‘snapshots’ of unit models for particular operating conditions.
- Modelfitting can then be achieved by logistic regression (strong synergies with information theory)
- Hence this is a machine-learning approach; I call it cheating!

Advantages of machine learning approaches

- Fast
- Maximum use of available information
- Profit benefit
- Reduced laboratory work
- Reduced analysis time
- Consistent with engineering concepts
- From a 'research' viewpoint numerous concepts to be validated – field wide open.

Main Project objectives

- Further development of tools and methods
- Validating the method with sponsors' industrial data
- Identifying plant performance improvement opportunities for project sponsors

Acknowledgements

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