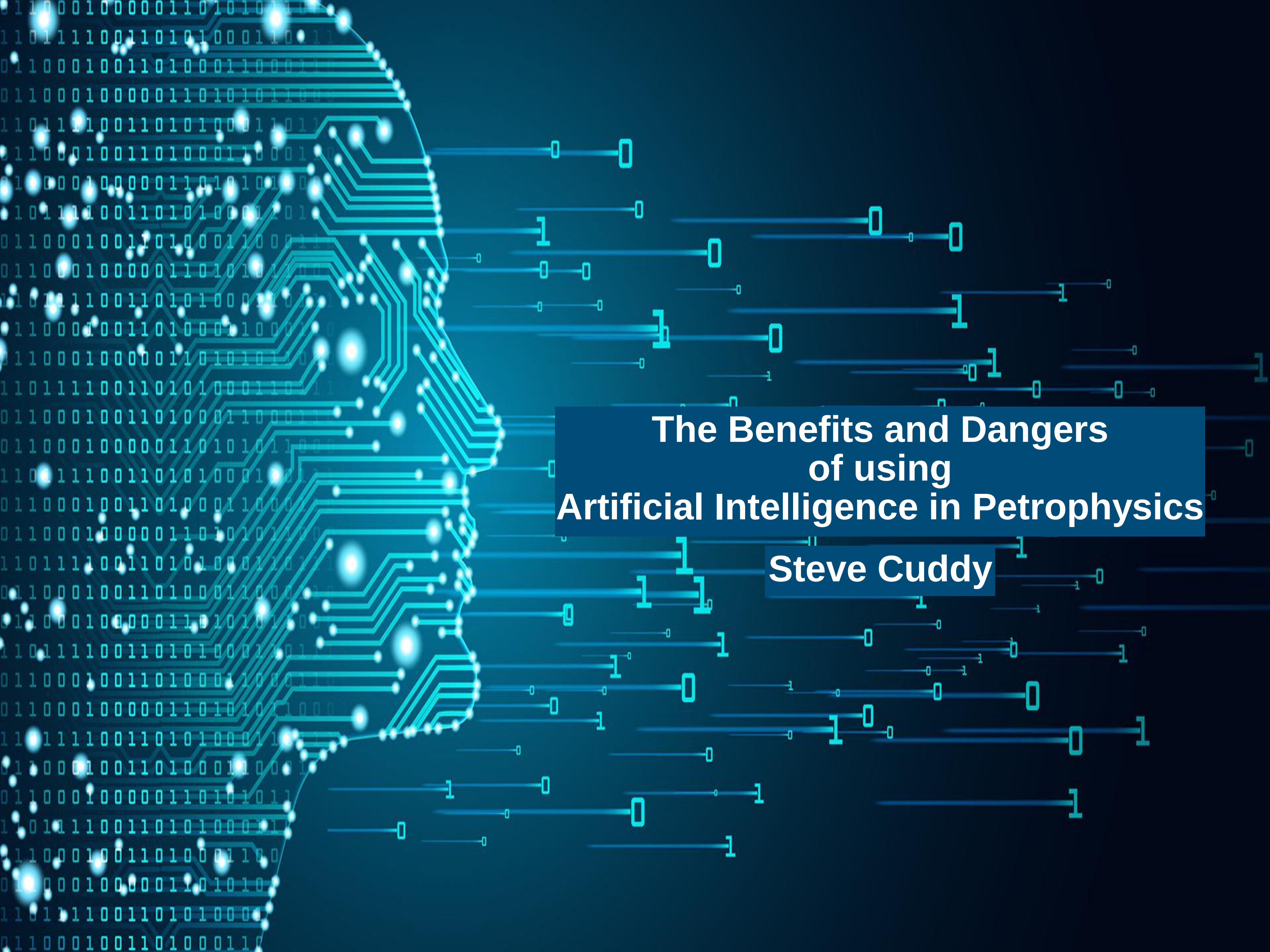


The Benefits and Dangers of using Artificial Intelligence in Petrophysics

Steve Cuddy

Outline

- What is AI?
- Case studies showing successful applications
- Benefits of using AI
- The grave dangers of using AI

What is Artificial Intelligence?

- Getting computers to imitate human intelligence – Alan Turing
- AI is data analysis that learns from data, identify patterns and makes predictions with the minimal human intervention
- First generation AI: Expert or Rule based systems
  - Simple petrophysics
  - IBM’s Deep Blue, beat chess Grandmaster Garry Kasparov in 1997
- Second generation AI: Machine learning
  - Evolution of water saturation equations, NMR spectra analysis
  - Google’s AlphaZero, self-taught computer program, easily beats all first-generation AI
- Third generation AI: The evolution of machine code
  - Using similar rules as used by life’s DNA code
  - True AI with general intelligence

AI requirements

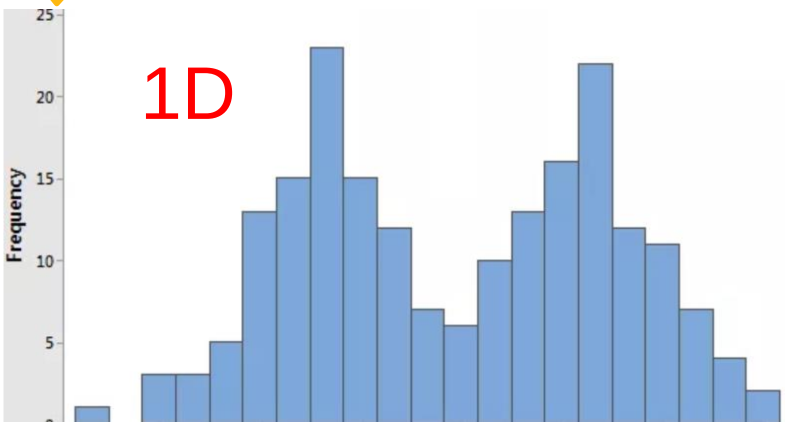
- You tell the AI what you want
  - The goal or fitness function
- The data
- Minimal human interaction
  - Doesn’t require prior knowledge of the petrophysical response equations
  - No parameters to pick or xplots to make

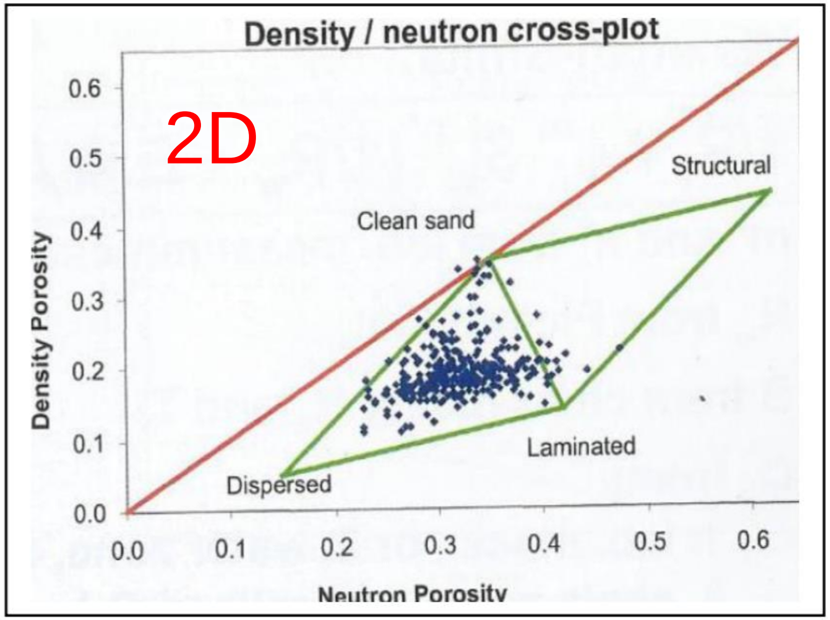
AI is given access to the data

These include:

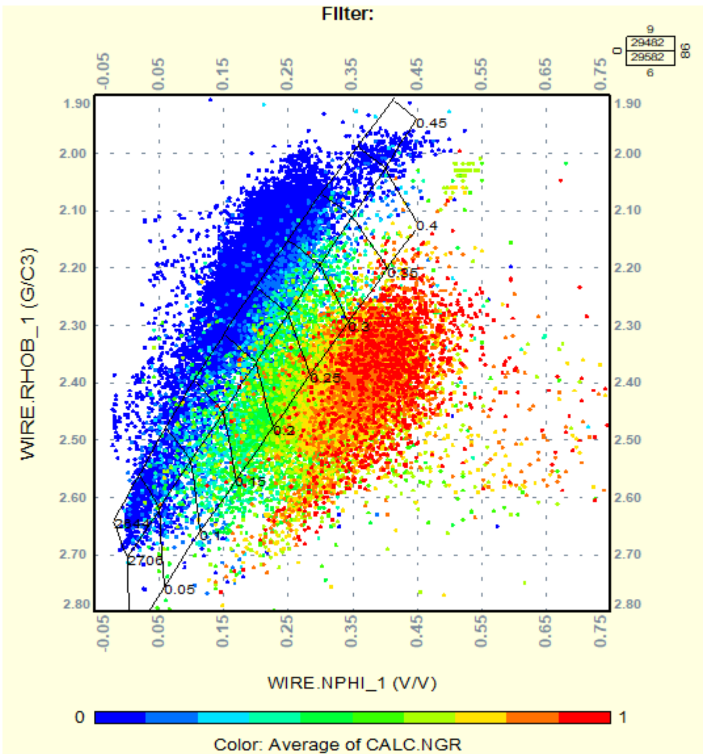
- Electrical logs - GR, Rhob, caliper, drho etc.
- Core data - porosity, core Sw, SCAL etc.
- Depth - measured and TVDss
- Gas - chromatography data
- Drilling data - ROP, Dexp etc.
- NMR - T1 & T2 distributions
- etc.

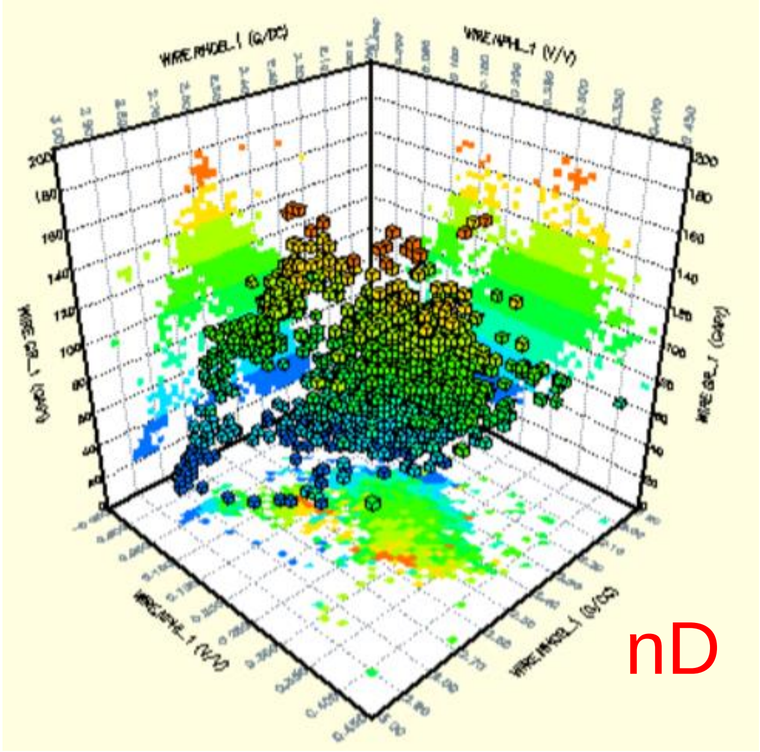
n-dimensional Data





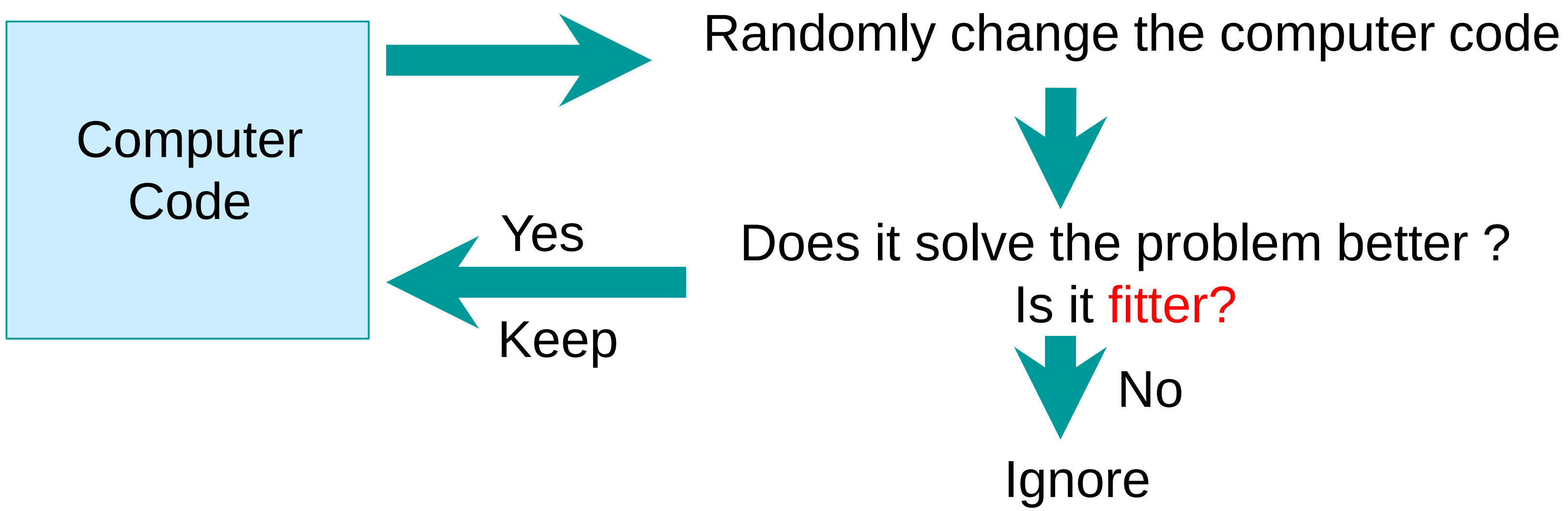
3D





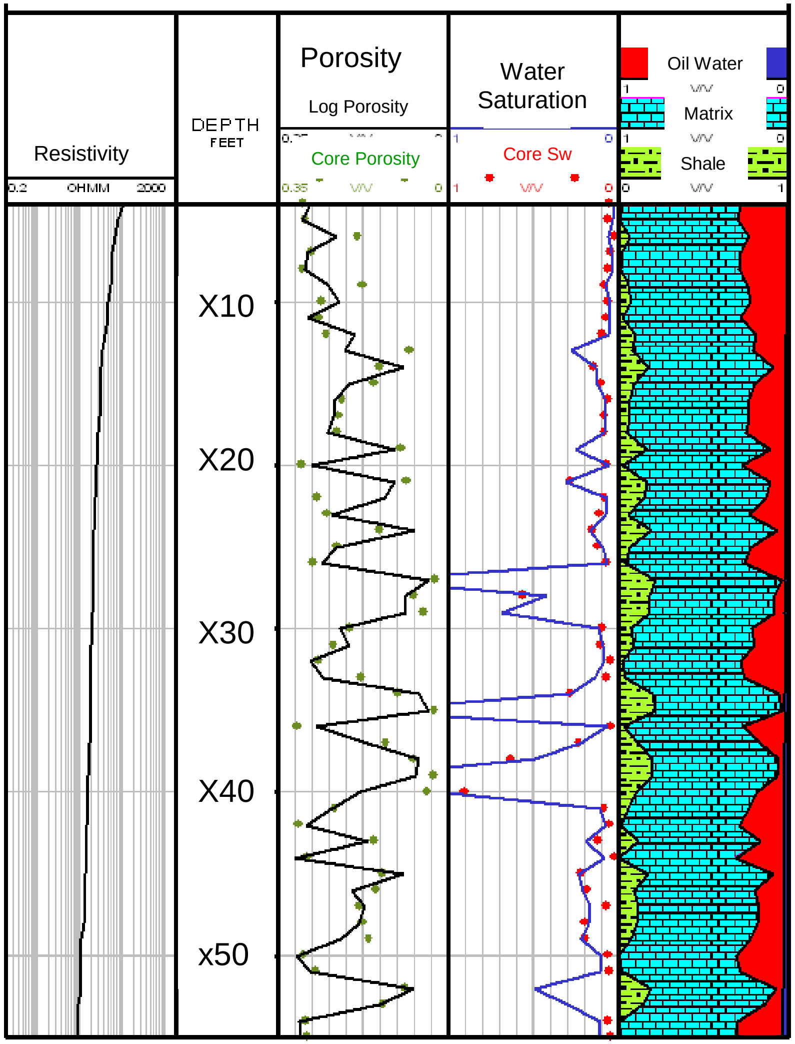
Second Generation AI

- We define the problem - Fitness Function
- We give the program access to the data
- The computer guesses the answer and through successive iterations (generations) ‘evolves’ the best answer



Middle East Carbonate Reservoir

- Case Study 1
- Client required a shaly sand equation to derive water saturation from the resistivity and gamma-ray logs
- Client wanted an independent check of the Special Core Analysis parameters ‘m’ and ‘n’
- Core water saturation available



Saturation Equation Determination

- Fitness Function – “determine an equation so that the resistivity predicted water saturations are as close as possible to core derived water saturations”
- AI may ‘re-invent’ the Indonesia or Simandoux equations or create a specific equation for the field
- Start by assuming Sw = Function (Porosity, Resistivity, Volume of shale)

$$Sw = \sqrt[n]{\frac{aRw}{Rt\phi^m}}$$

$$\frac{1}{\sqrt{R_t}} = \left[\frac{V_{sh}^{(1-Vsh/2)}}{\sqrt{R_{sh}}} + \frac{\phi^{m/2}}{\sqrt{aR_w}}\right] S_w^{n/2}$$

Sw	= Water saturation
ϕ	= Porosity
Rt, Rsh, Rw	= Resistivities
Vsh	= Volume of shale
a, m, n	= constants unknown

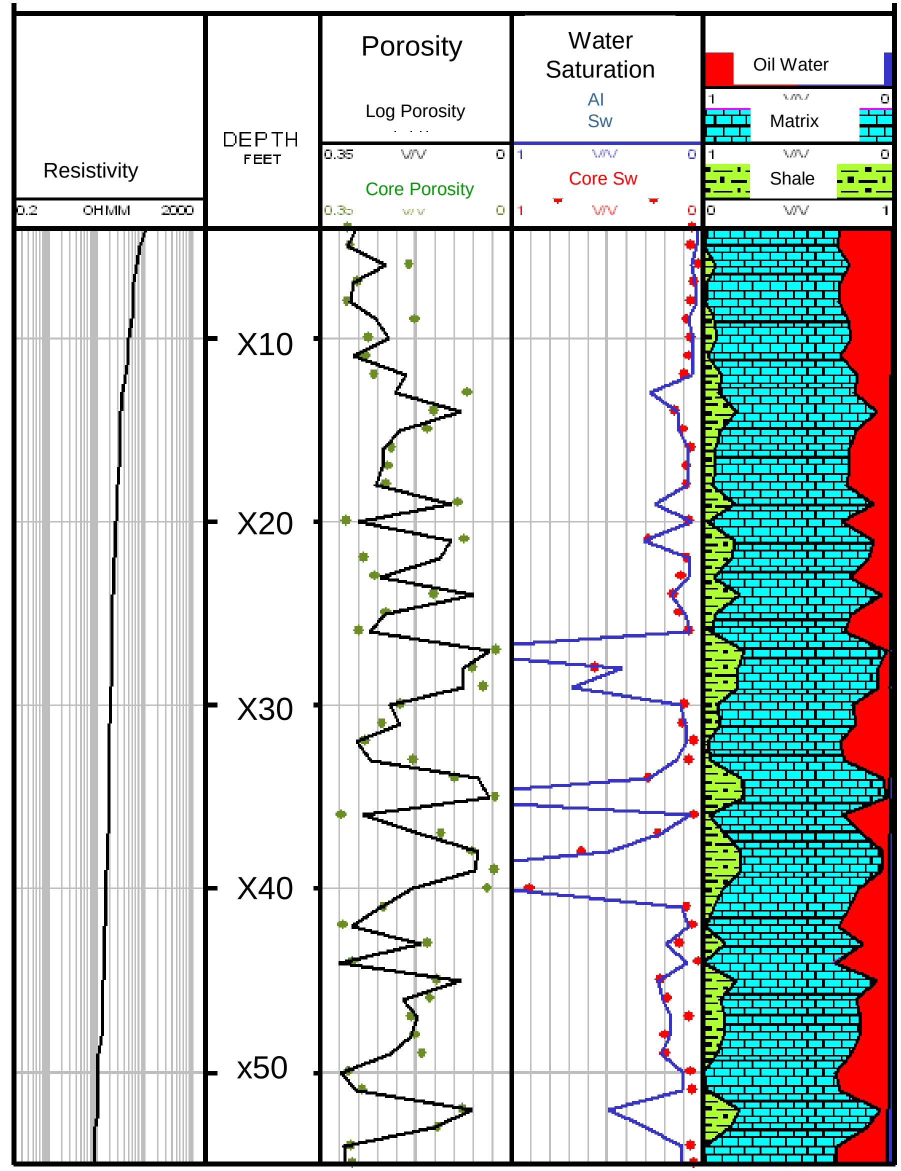
Middle East Carbonate Reservoir

- Core water saturations essential
- Fitness Function
  - "Find the best shaly sand equation so that the resistivity derived Sw matches the core Sw"
- Result:

$$\frac{1}{Rt} = \frac{\phi^m Sw^n}{Rw} + bVsh^c$$

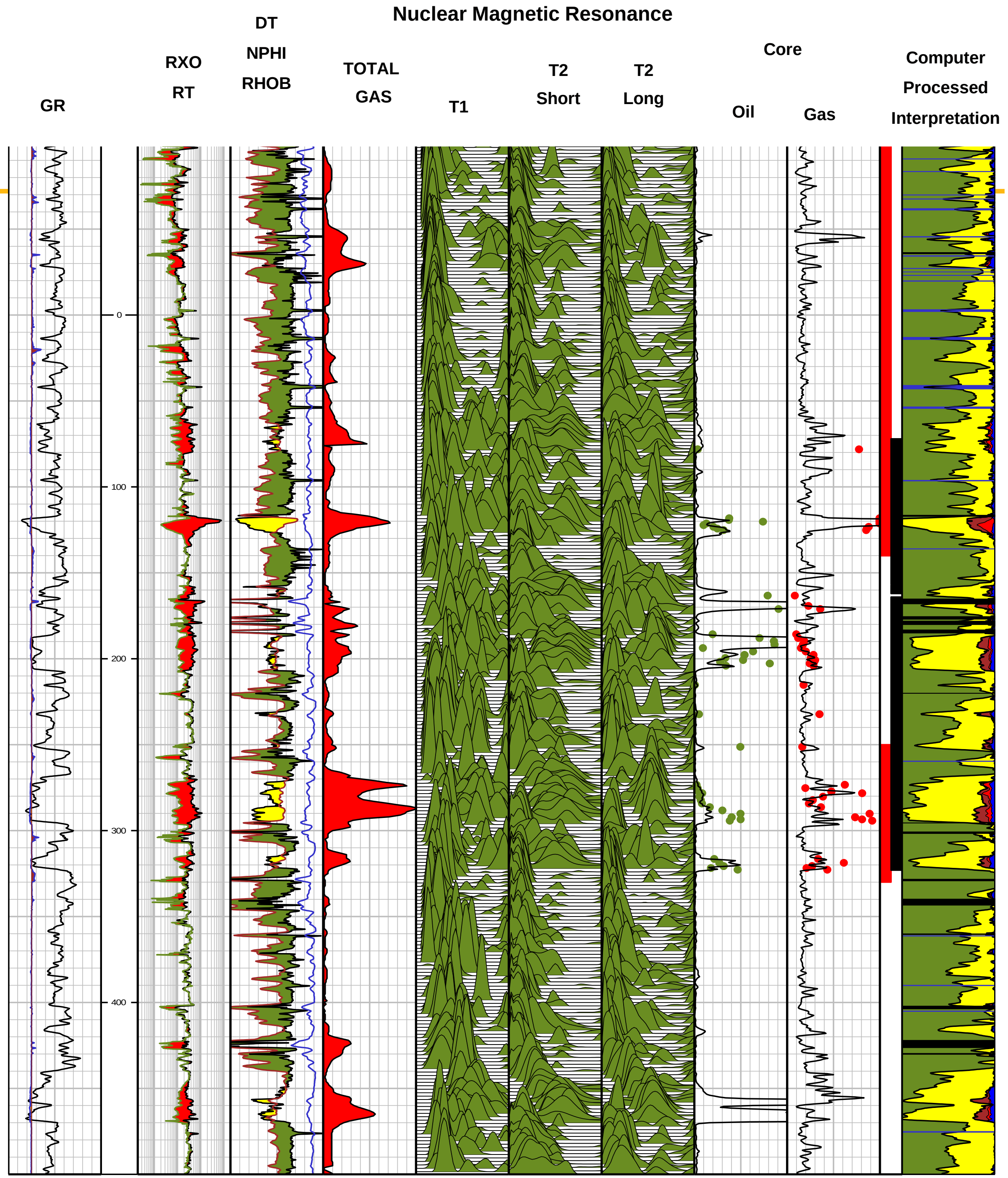
Sw	= water saturation
ϕ	= porosity
Rt, Rw	= resistivities
Vsh	= shale volume
m,n,b,c	= constants

- Special Core Analysis from AI:
  - Cementation exponent (m) 2.214
  - Saturation exponent (n) 1.751



NMR Pattern Recognition

- Case Study 2
- UKCS gas field with an oil problem
- Data:
  - Conventional logs
  - NMR T1 and T2
  - Gas Chromography
  - Core derived oil and gas saturations

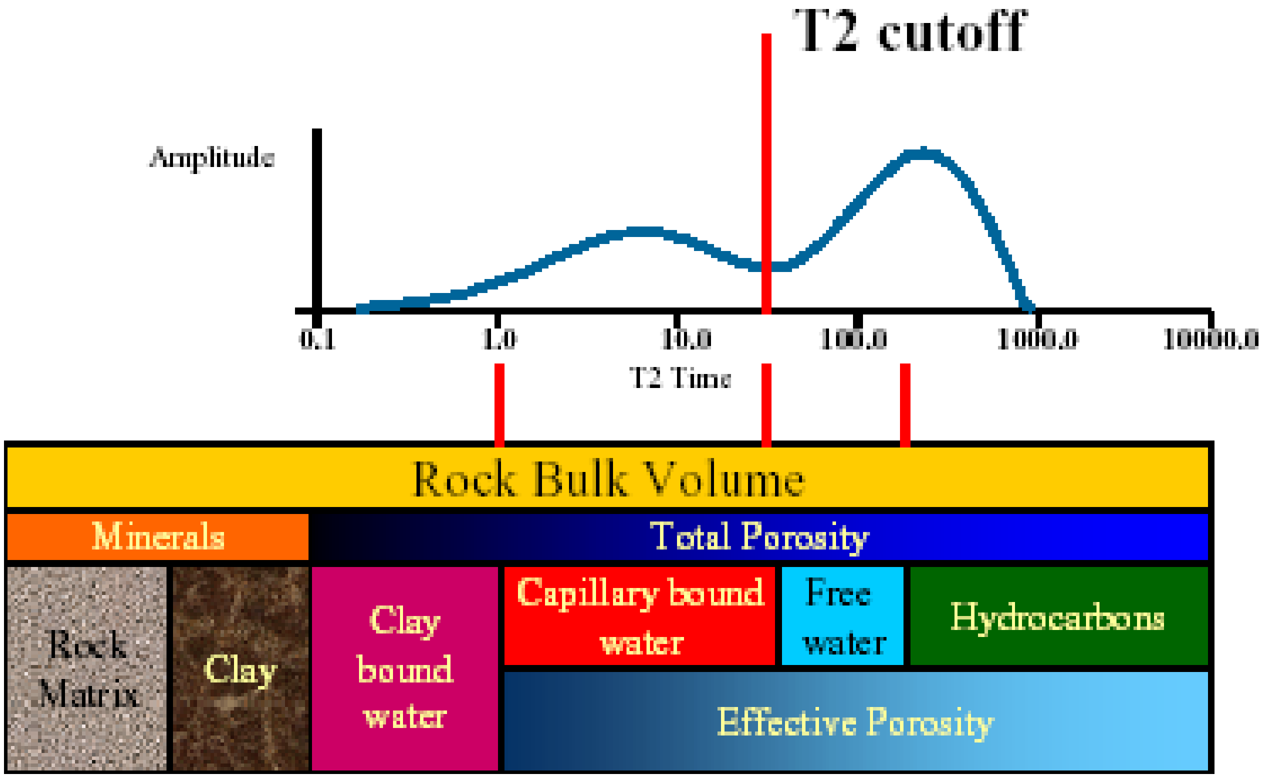


Case Study 2 – NMR Pattern Recognition

- A gas field with an oil problem
- Residual oil pockets remain within the main gas reservoir
- This oil is highly viscous
- If produced could block up production tubing

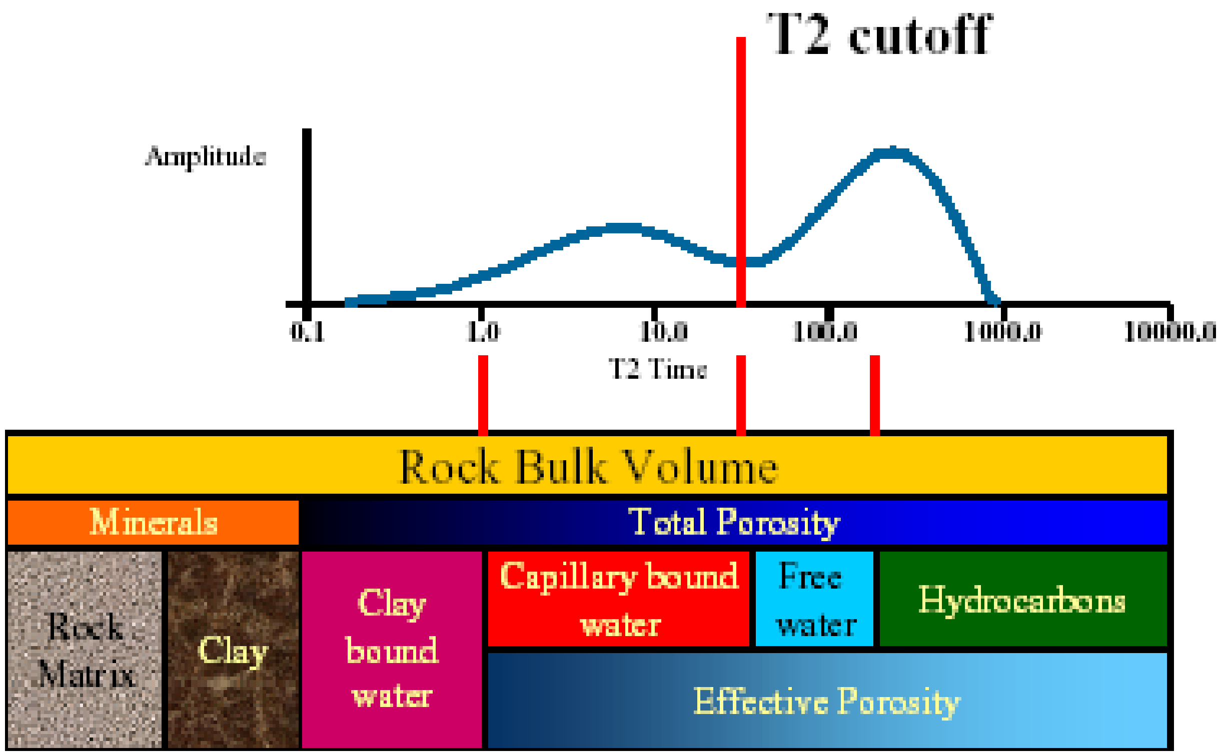
- The client needs to identify oil and gas in order to only perforate the gas zones
- Conventional petrophysical techniques like density / neutron porosity separation can’t differentiate oil and gas due to thin beds and shaly formation

Nuclear Magnetic Resonance



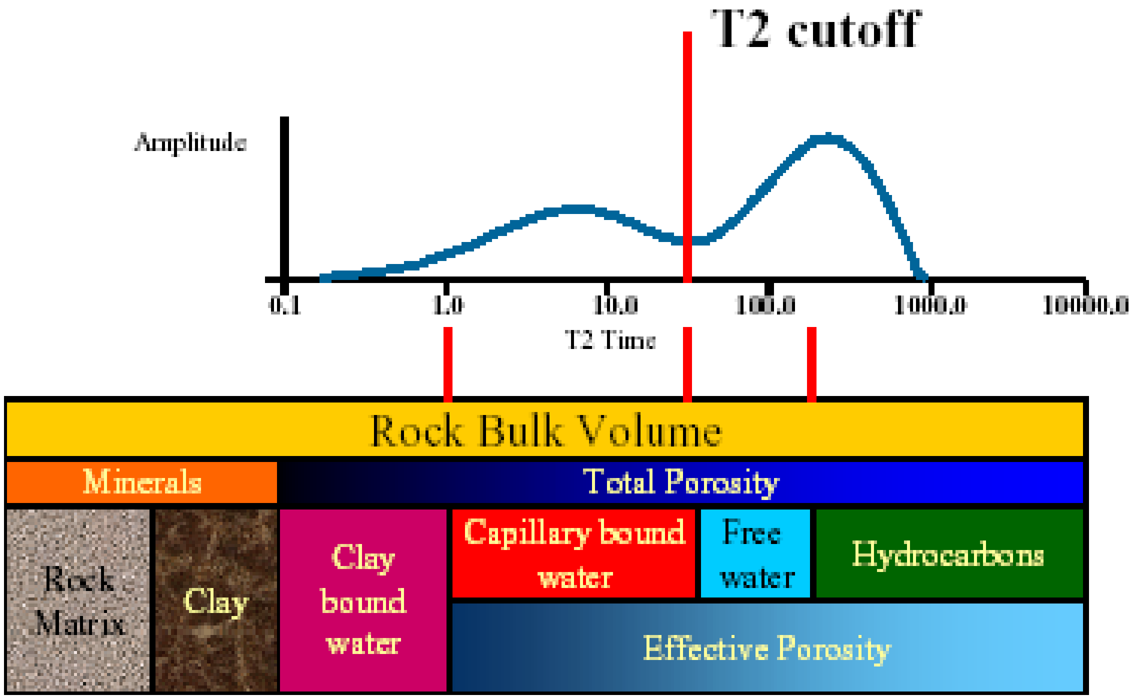
- The problem solved with nuclear magnetic resonance (NMR)
- This measures how hydrogen atoms respond to a magnetic field

Oil and Gas identification using NMR



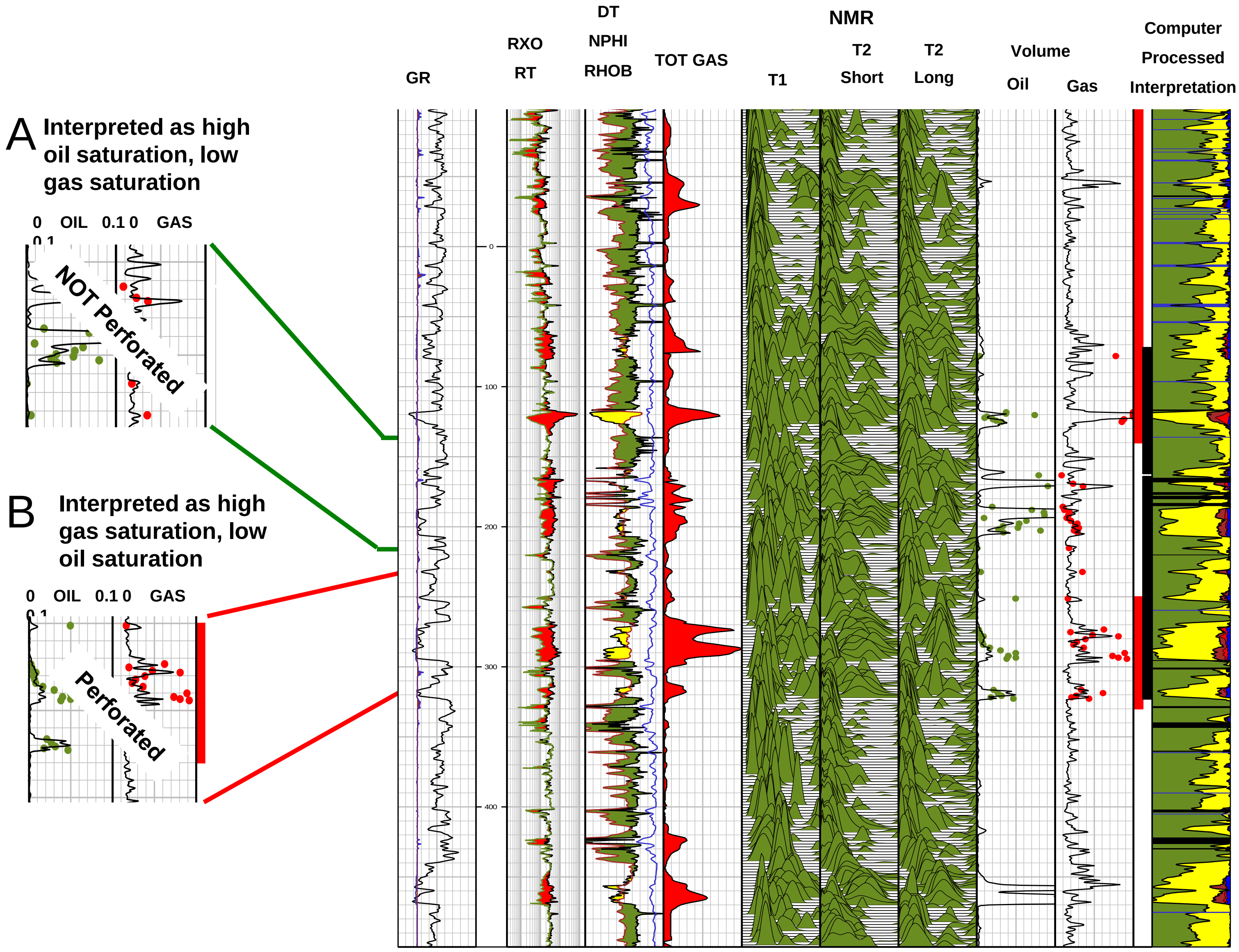
- Conventional NMR methods uses the Coates or Schlumberger-Doll-Research (SDR)
- These use very little of the wealth of information contained in the T2 spectrum!

Oil and Gas identification using the NMR and AI



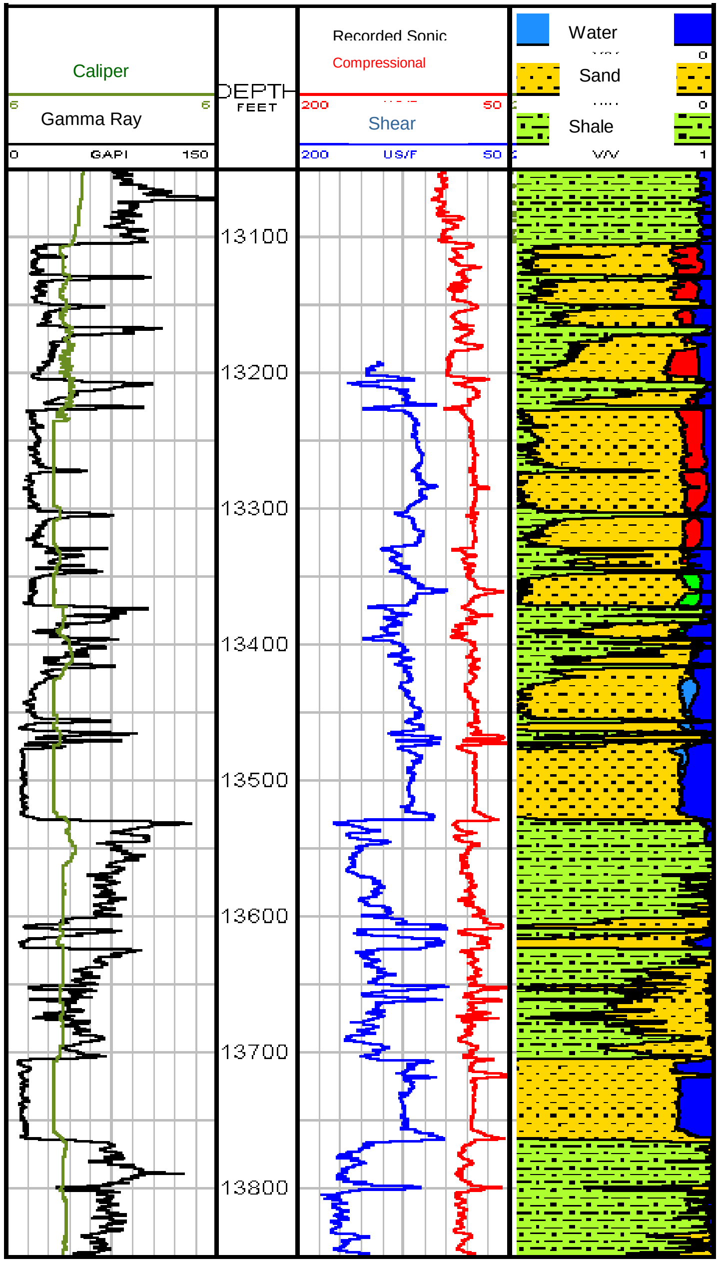
- AI determines the NMR spectra (waveforms) associated with core derived oil and gas analysis
- It then predicts the fluid content of all the reservoir beds
- Fitness Function: “Determine the wave-forms that give the best match between the log and core derived oil and gas saturations in the reservoir”

Results – Real time identification of gas and oil zones



Case Study 3 Shear Velocity Prediction using AI

- North Sea Field
- Only four wells have recorded shear velocity data
- Shear velocity is required on all 30 wells



Shear Velocity Prediction using AI

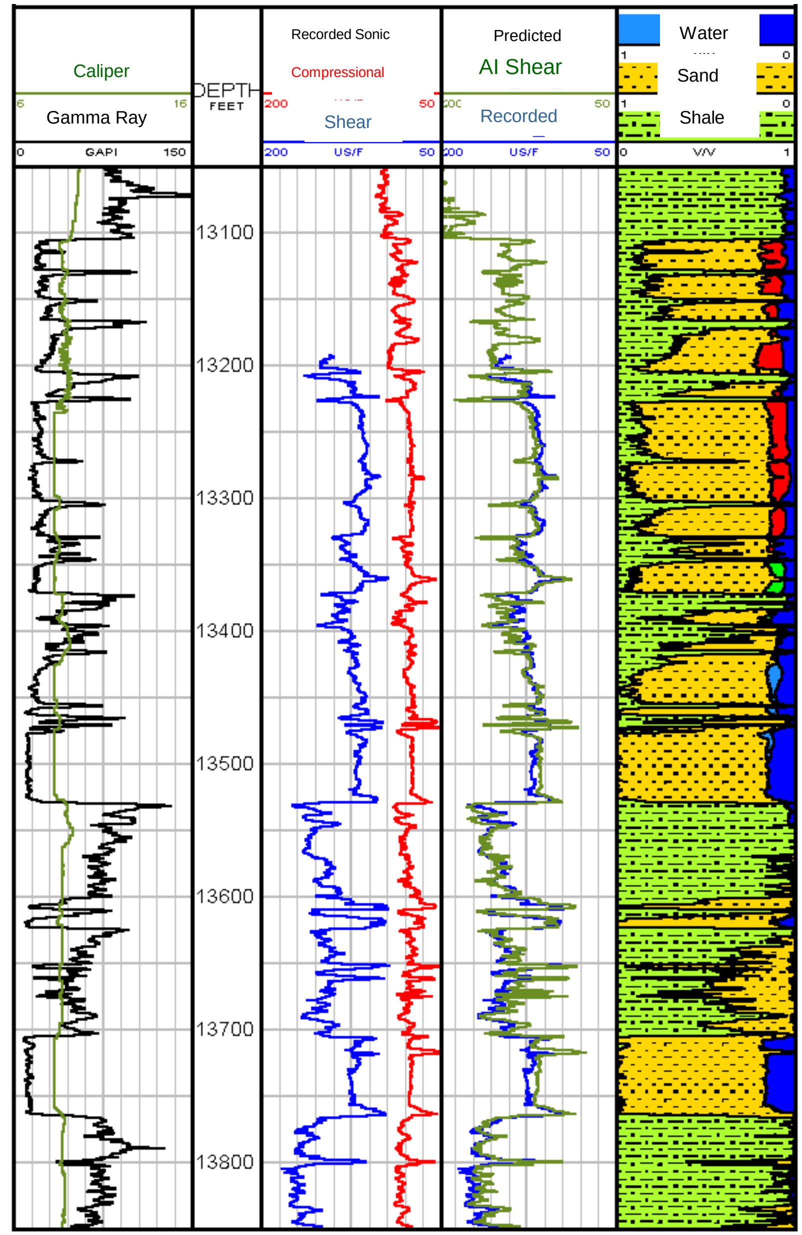
Fitness Function – "Determine a relationship so that the predicted shear velocities are as close as possible to log derived shear velocities"

Shear velocity = Function of:

- Conventional logs
- Drilling data
- Gas chromography data

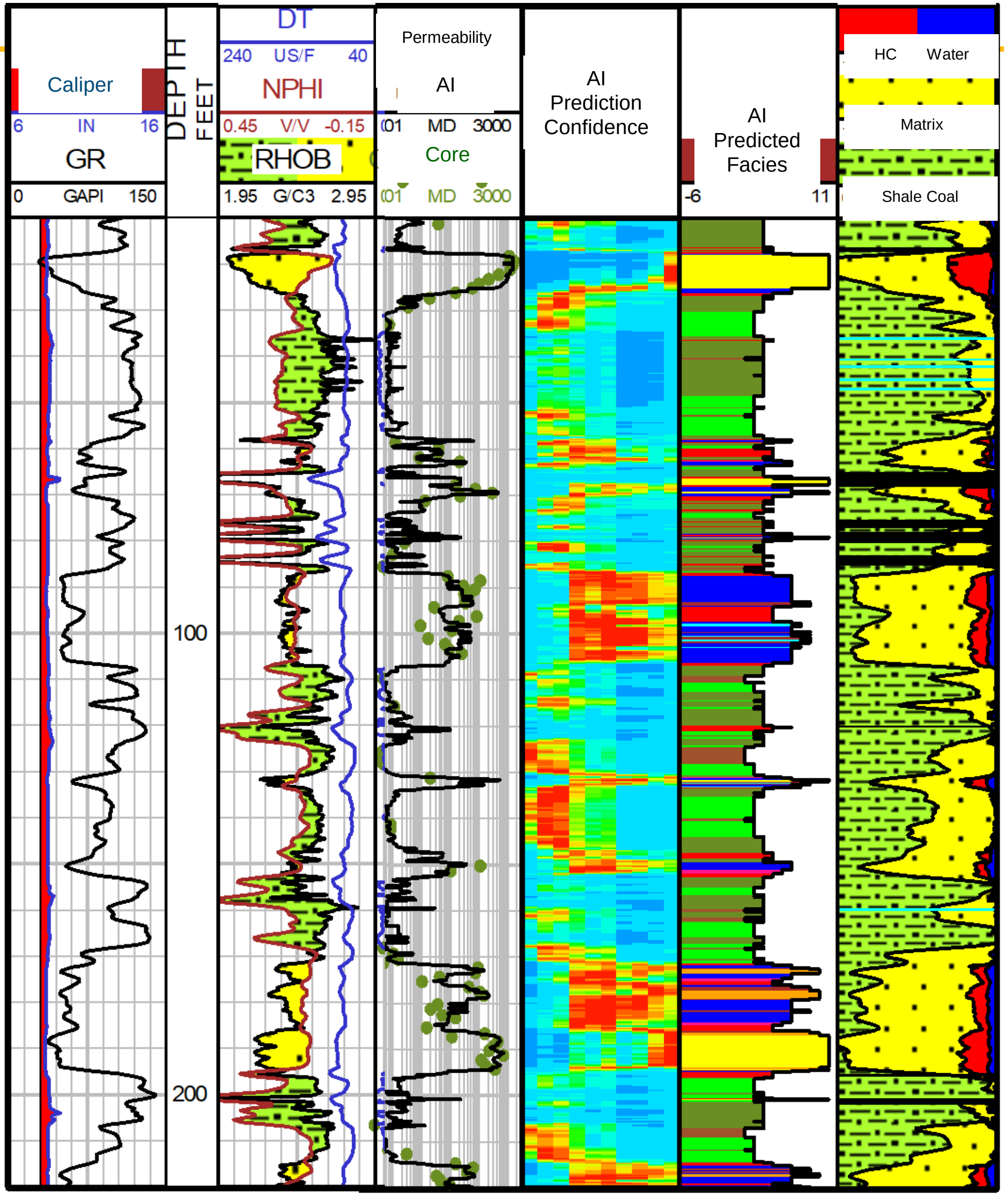
The AI gives the relationship

The AI predictions are better than the recorded logs!



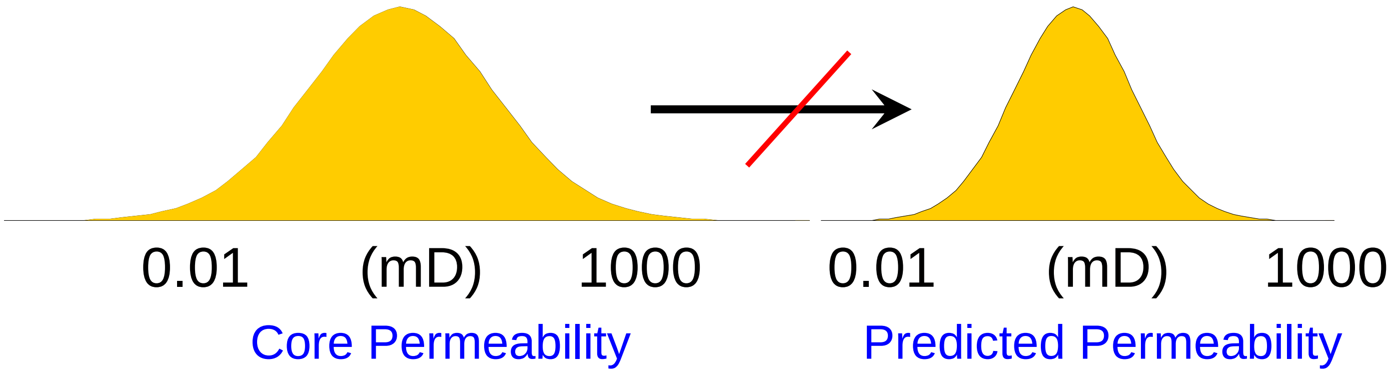
Permeability Prediction

- Case Study 4 - North Sea Field
- AI first predicts facies type
- Permeability then predicted based on facies type and other all logs
- Is the AI permeability any better than from regression analysis?



AI predicts permeability that upscales correctly

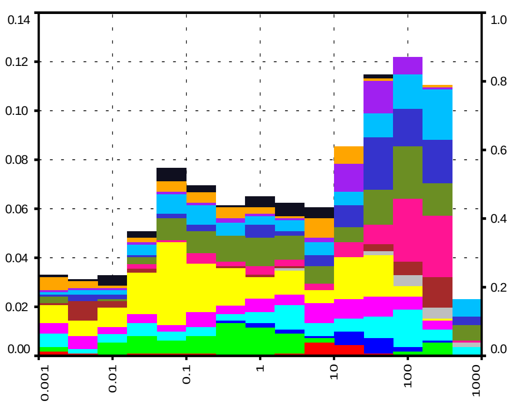
- Log and core permeabilities represent typically 2 feet
- To be used in a reservoir model the predicted permeabilities must upscale correctly
- They must have the same dynamic range as the core data



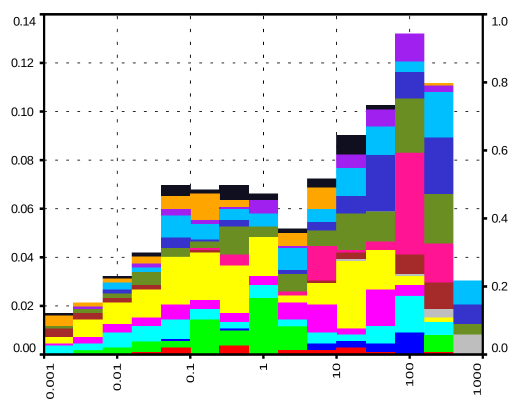
- Least square methods regresses toward the mean
- AI preserves the dynamic range

Core Permeability Distributions

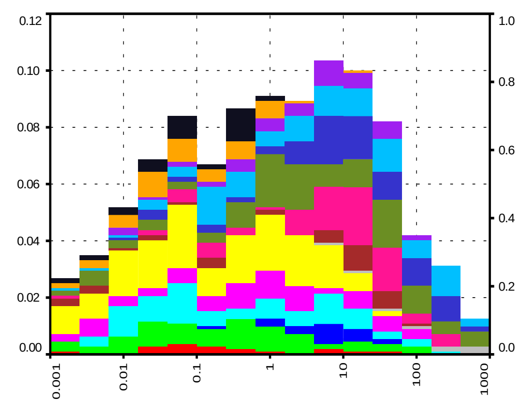
Core distribution



AI prediction



Linear Regression



- Permeability frequency plots (mD - log scale)
  - Colour represents data from 15 cored wells

- AI predicted permeability matches core distribution

- Regression permeability techniques are poor at the extremes and therefore will be incorrect when upscaled

Case Study 5 – Quality Control and Repair of Electrical Logs

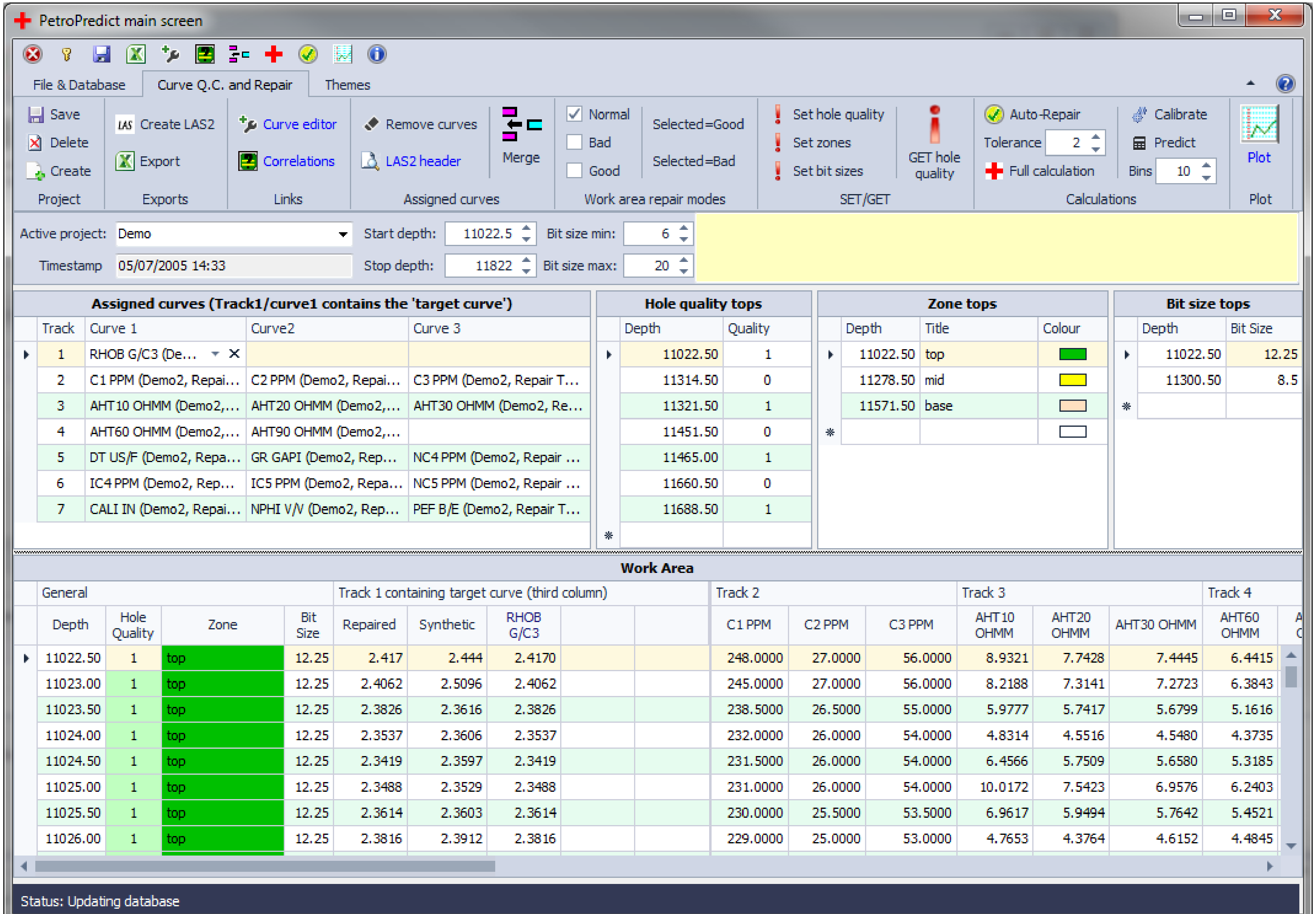
- It is essential to confirm log quality before they used by the petrophysicist

- AI automatically identifies and repairs poor logs
  - Washouts
  - Gaps
  - Poor readings

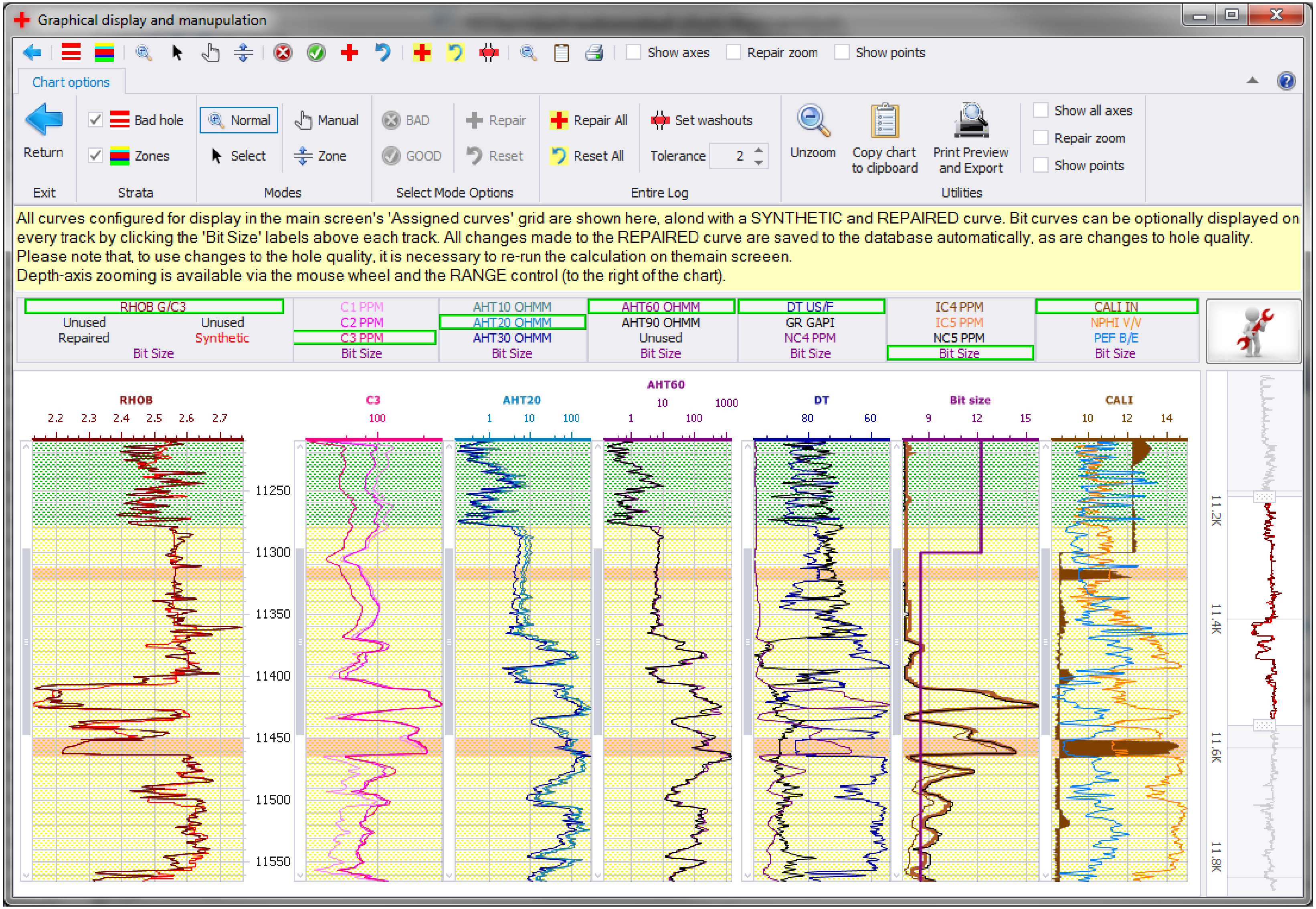
- Doesn't require a skilled user

- Baker Hughes developed free AI software

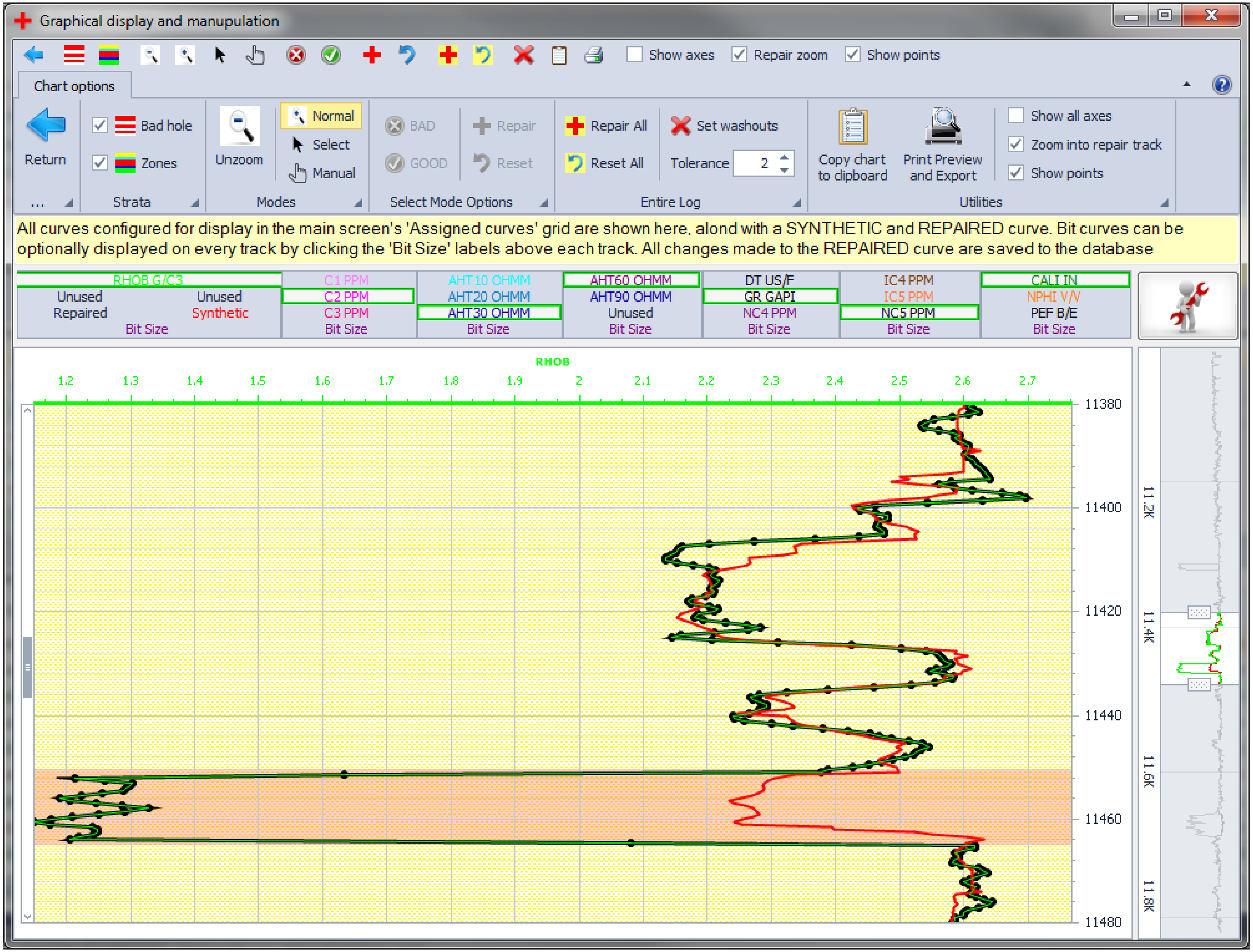
Quality Control and Repair of Electrical Logs



Quality Control and Repair of Electrical Logs



Quality Control and Repair of Electrical Logs

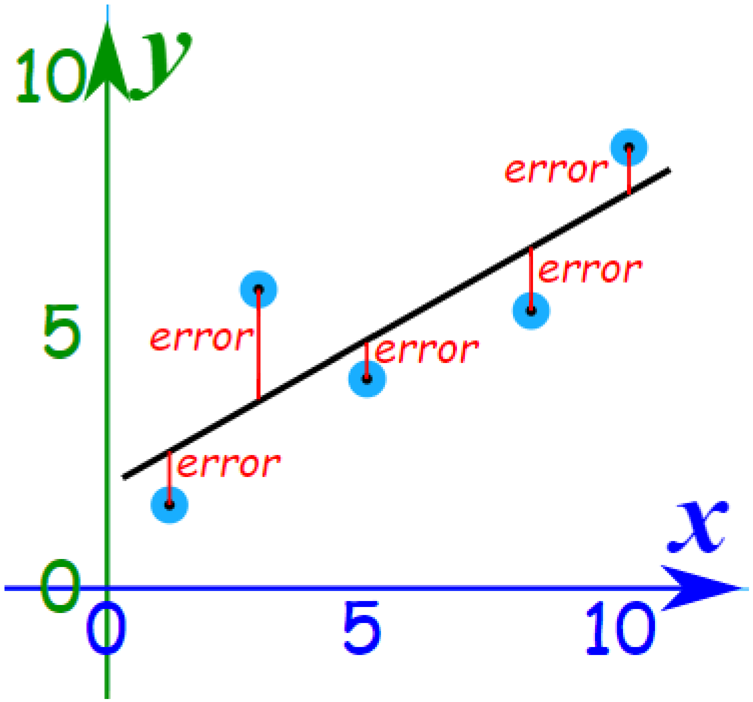


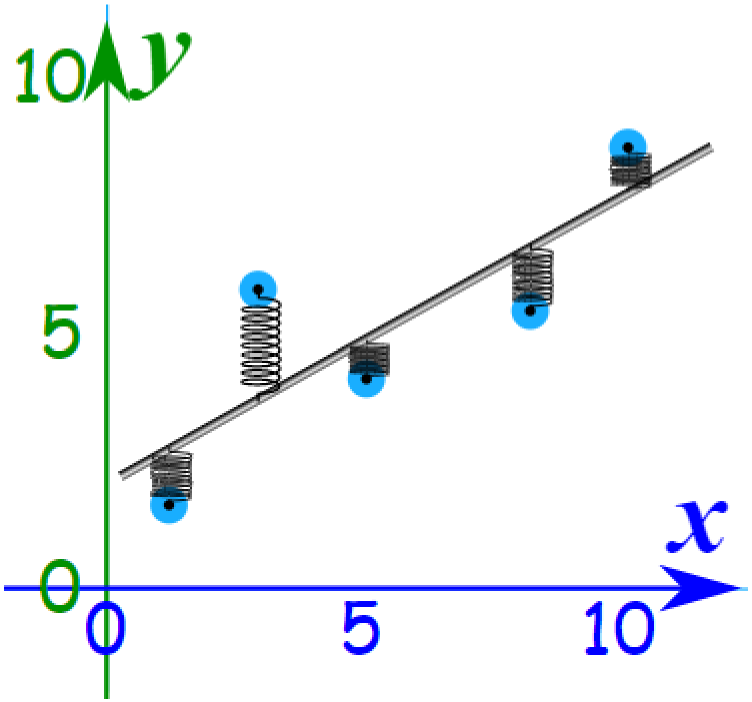
Advantages of AI in Petrophysical Analysis

- AI doesn’t require prior knowledge of the petrophysical response equations
- AI is self-calibrating. Just give it the data
- AI avoids the problem of “rubbish in, rubbish out”,
  - by ignoring noise and outliers

Linear Regression

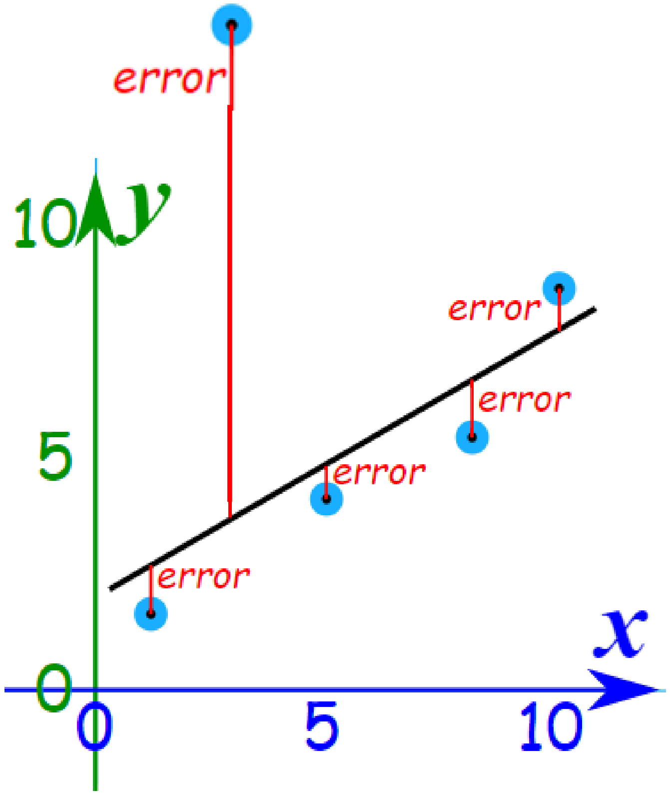
- AI finds relationships in the data in order to make predictions
- Least squares regression is often used
- This minimises the sum total of the square of the errors





Linear Regression

- Least squares regression is undemocratic
- Outliers unfairly influence the result
- A point 10 times further from the line has a 100x the weighting
- It is very difficult to manually remove these and would introduce human bias
- Outliers may be valid data
- Best keep them and minimise the linear distance rather than the squared distance
- Random noise should be swamped by valid data



Advantages of AI in Petrophysical Analysis

- AI doesn’t require prior knowledge of the petrophysical response equations
- AI is self-calibrating. Just give it the data
- AI avoids the problem of “rubbish in, rubbish out”,
  - by ignoring noise and outliers
- There is very little user intervention
  - There are no parameters to pick or cross-plots to make
- AI programs work with an unlimited number of electrical logs, core and gas chromatography data; and don’t ‘fall-over’ if some of those inputs are missing
- It is not a Black Box as it provides insights into how it makes predictions

Narrow vs. General AI

- Narrow AI is like apps on your smart phone
  - Forecasts the weather, converts currencies
  - Orders coffee for you

- General AI, like humans can do many things
  - Play chess and do petrophysical analysis

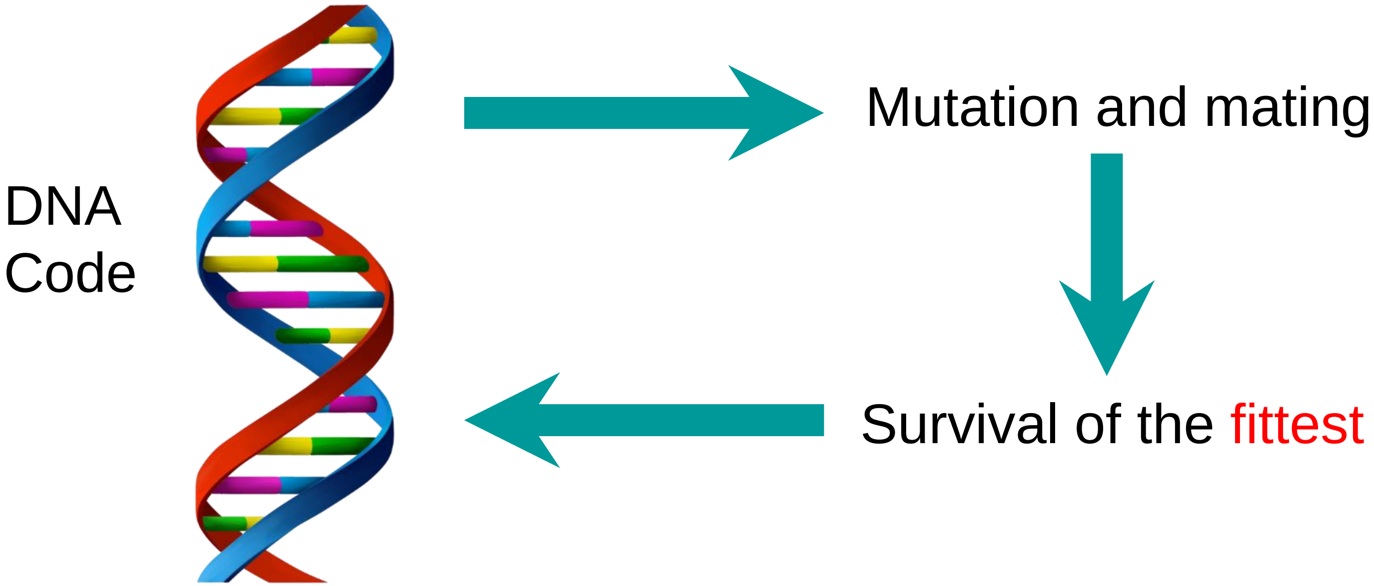
- General AI
  - Learns from one specialist area and applies in another
  - They will be genuinely creative with the ability to produce something original and new
  - General AI is True AI

Third Generation AI

- AI programs currently being developed include ones where their machine code evolves, using similar rules used by life’s DNA code

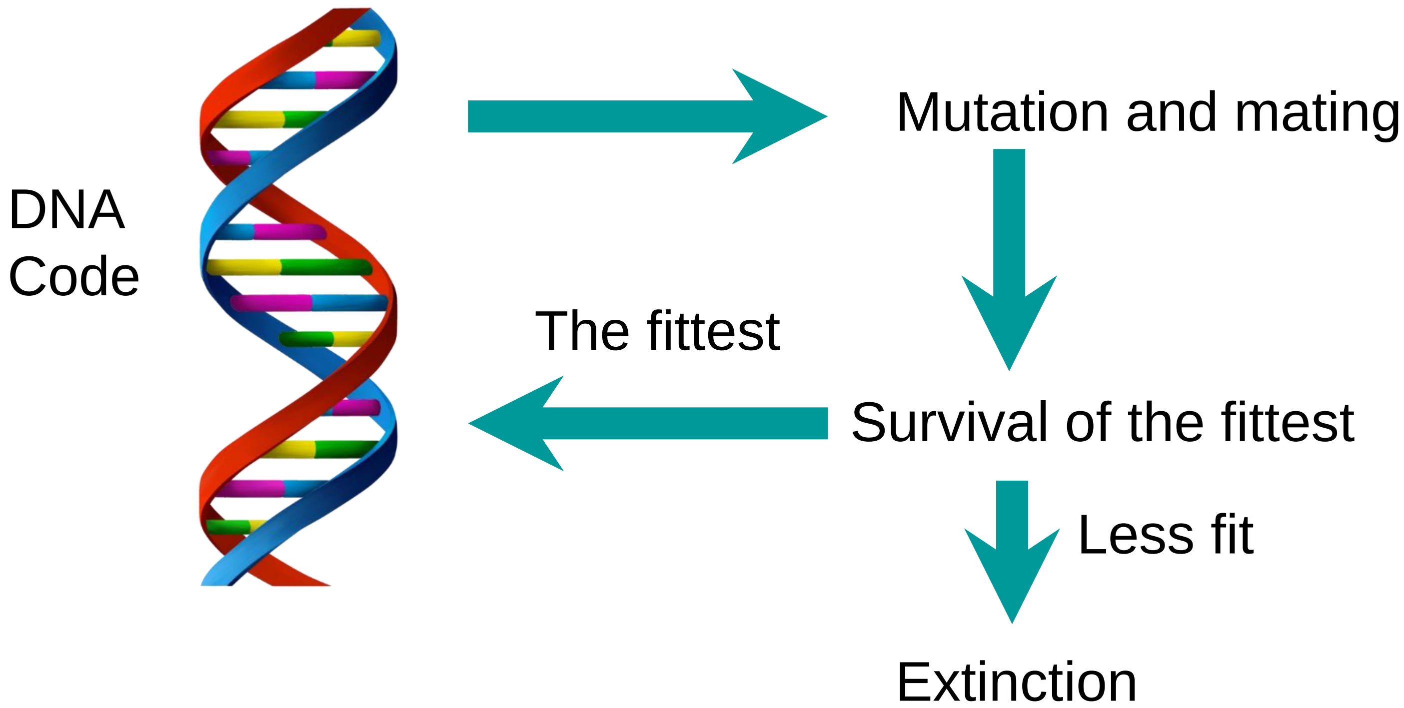
Evolution in Nature

- Charles Darwin - The origin of species by means of natural selection
- DNA language code - 4 characters - A, T, C, G



Evolution in Nature

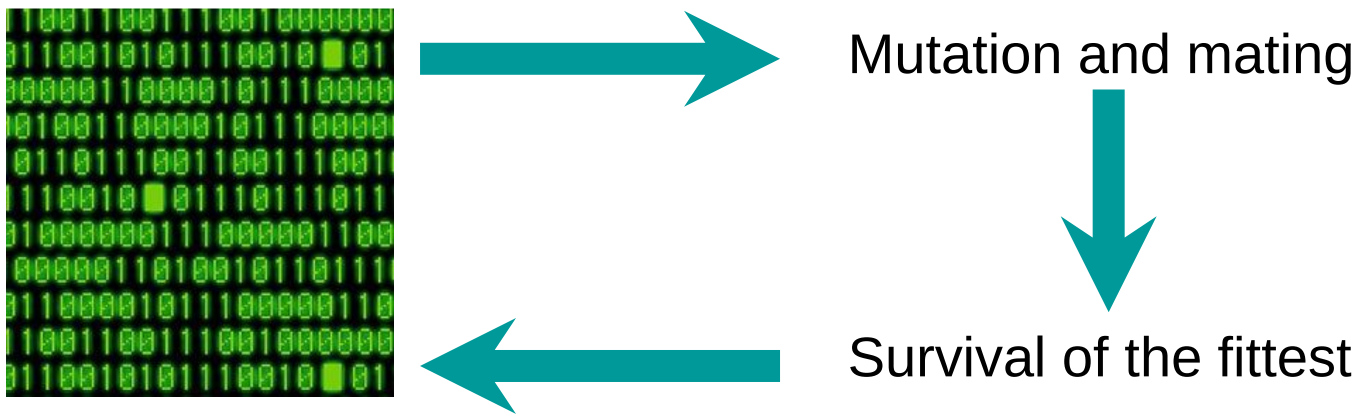
- Feedback loop – takes millions of years



Third Generation AI

- Just define the problem to be solved – Fitness Function

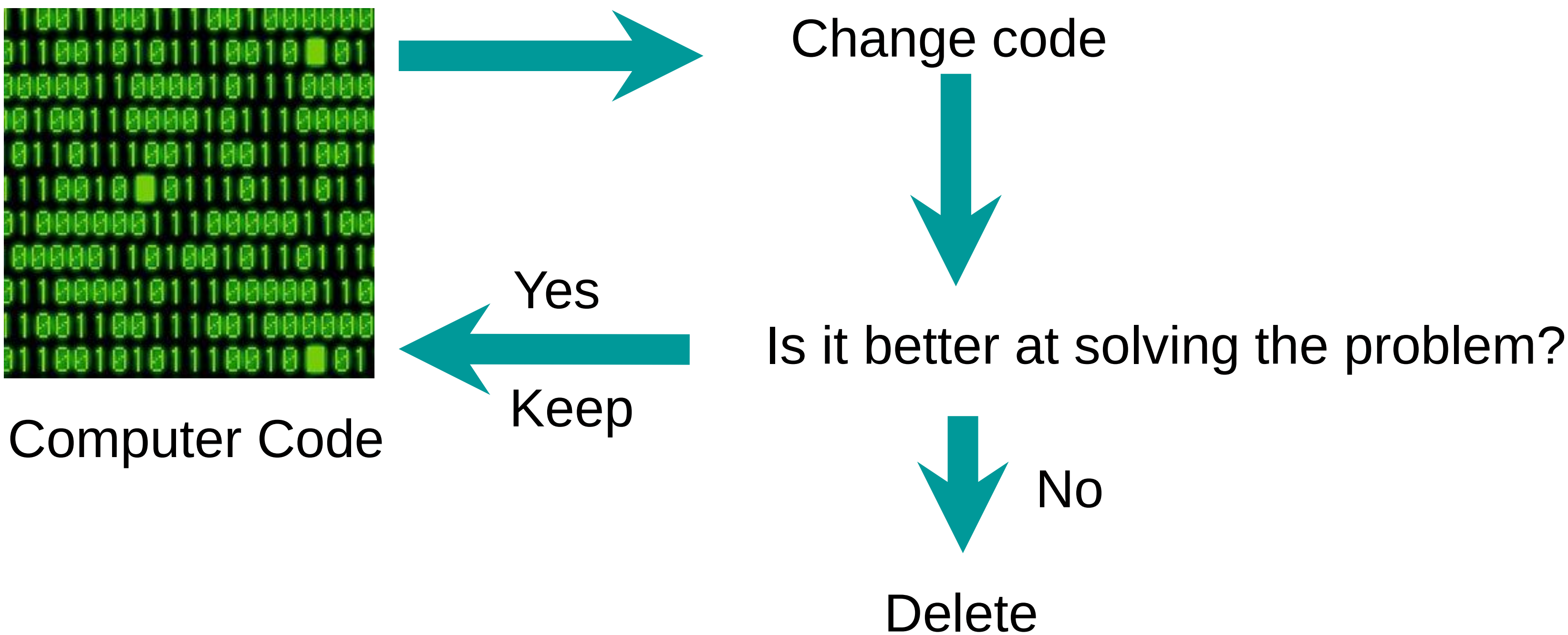
Computer Code



A language of 2 characters

Third Generation AI

- Let the machine code mutate and mate using the Rules of Life



AI requirements

- Data
- Fitness Function
  - Tells the AI what you want it to do
  - Written in plain English
  - Does the AI understand what you really want?

King Midas and his golden touch

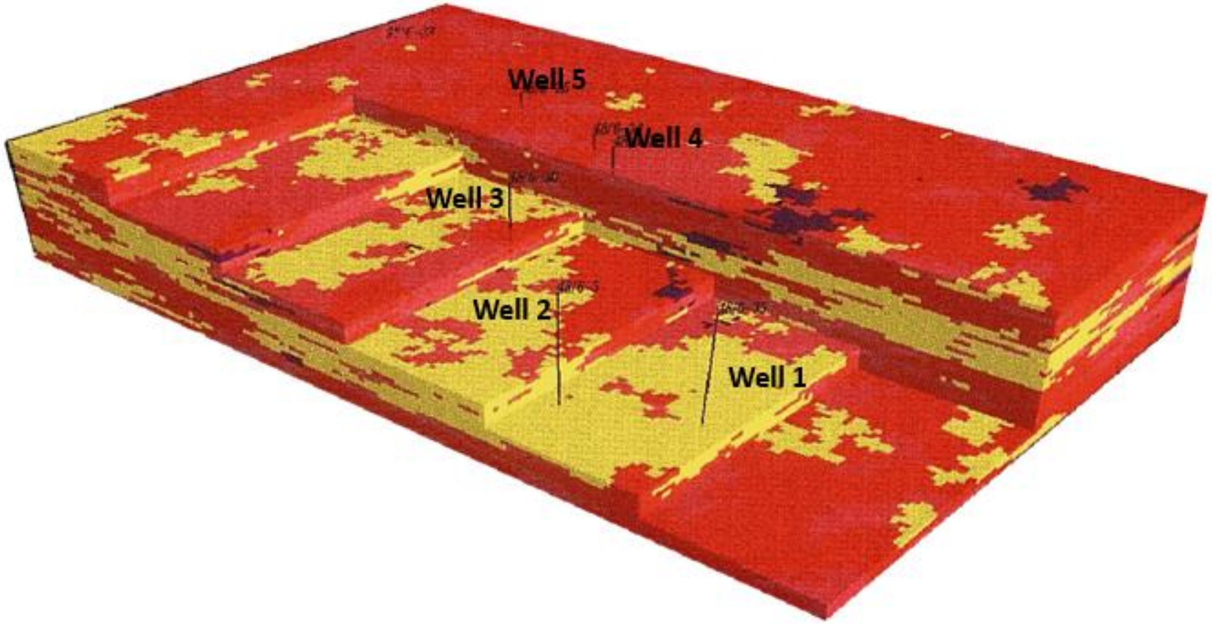
- King Midas, in Greek mythology, was granted his wish that everything he touched into gold
- He didn’t realise that this included his food and his children
- Similarly an ill-conceived Fitness Function may give unexpected results

The sorcerer's apprentice

- The apprentice uses magic to get a broom carry water for him
- Unfortunately it runs-away and nearly drowns him
- Similarly a runaway AI may not be stoppable
- An example from petrophysics

Example of Runaway AI

- History matching
- Fitness Function – “get the best match as fast as possible”



Example of Runaway AI

- By trial and error the computer will evolve a fast history match
- Any endeavour succeeds faster if you increase its resources
- A human programmer / hacker may co-opt the resources of other network computers to achieve the faster speed
- There is no reason why AI couldn’t also doing this
- If AI achieves this ‘by accident’- there is nothing to stop it doing it again and again
- Evolution takes millions of years
- The computer makes millions of iterations per second

Runaway AI

- The AI may ‘accidently’ start improving exponentially
- A supercomputer isn’t required to do this
- An elaborate computer program isn’t required
  - Only one that can update its own machine code
  - Only one with an ill-judged Fitness Function
- This is known as **the singularity** where artificial intelligence becomes uncontrollable and irreversible
- The chances of this happening may be as remote as life spontaneously occurring
- AI has only to do this once
- It is not known how to stop computers with run away evolution

The Dangers of AI

- Professor Stephen Hawking (University of Cambridge Professor)
  – “Efforts to create thinking machines pose a threat to our very existence“
- Bill Gates (Microsoft co-founder)
  – “Humans should be worried about the threat posed by artificial Intelligence”
- Nick Bostrom (University of Oxford Professor)
  – “We’re like children playing with a bomb”
- Elon Musk (SpaceX founder)
  – “AI needs safety measures before something terrible happens”

Solution to Runaway AI

- These AI programs pose considerable dangers far beyond the oil industry
- A 'risk assessment' is essential on all AI programs so that all hazards and risk factors, that could cause harm, are identified and mitigated
- The possibility of a runway AI, in the near term, is remote
- But the consequences could be greater than climate change and nuclear proliferation
- A risk assessment need only take a few minutes
- AI programs are potentially dangerous and may be the last thing humans invent

Conclusions

- AI can make petrophysical analysis very easy
- AI can be very dangerous
  - AI program development should include a risk assessment
- Questions?