Using CoFI to experiment with geophysical inversion

The Anatomy Lesson of Dr. Nicolaes Tulp

This will be an interactive session where participation is encouraged

A **Co**mmon **F**ramework for **I**nference

AuScope · CSIRO · Australian National University · InLab

What is inference and inversion

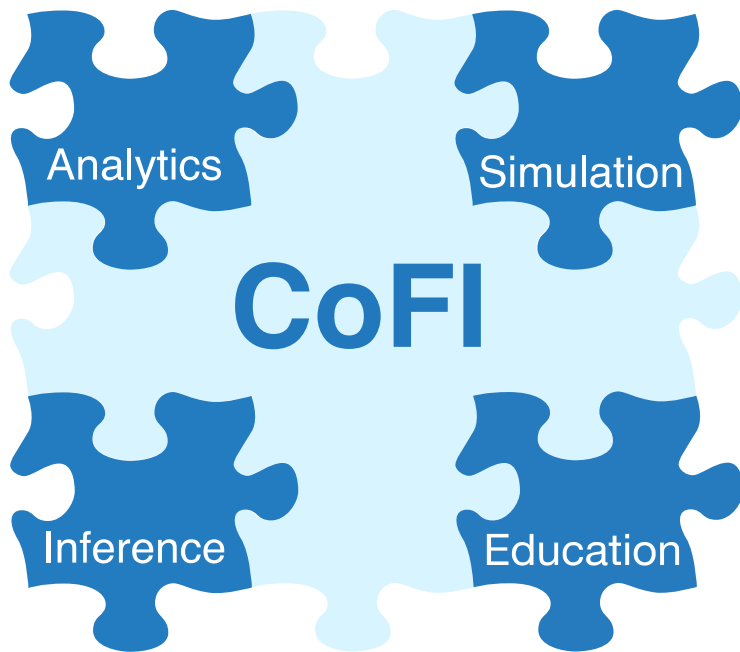*Shadow sculptures by Tim Noble and Sue Webster*

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What is inference and inversion

Shadow sculptures by Tim Noble and Sue Webster

A **Co**mmon **F**ramework for **I**nference

Vision
CoFI provides industry, academia and government with a software platform underpinning research, training, and services in the application of inference methods to data.
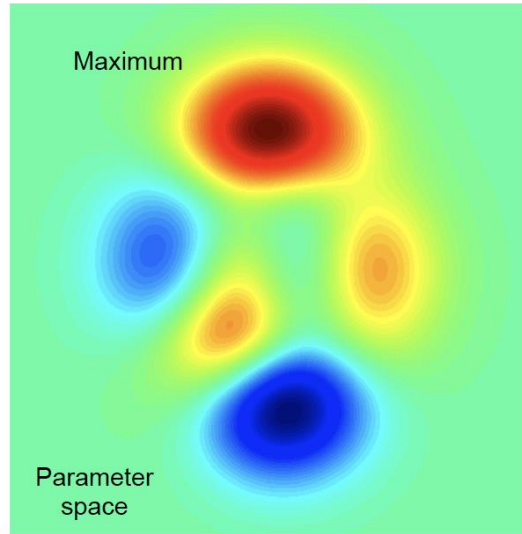
- *Lower barriers in access to leading edge approaches*

- *Reduce time in application of inference methods to data*

- *Interactive education environment for training in inversion*

"A good example is the best sermon"
— Benjamin Franklin

https://inlab.au/cofi/

Two approaches to inversion

Parameter estimation

Maximum
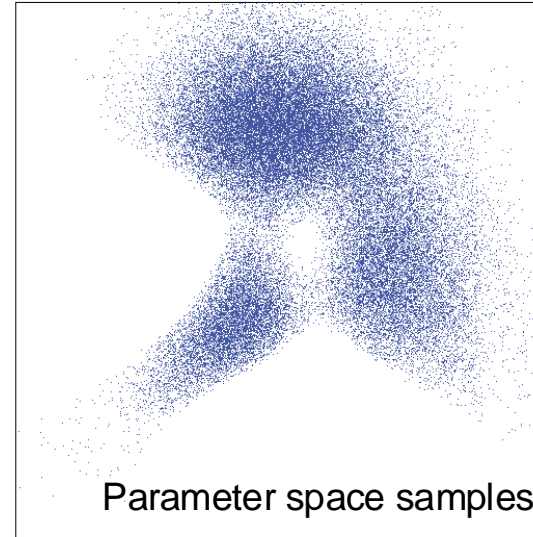
Parameter
space

Optimisation of a misfit function

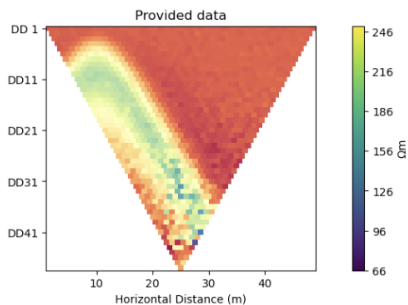$$\phi(\mathbf{m}) = ||\mathbf{d} - g(\mathbf{m})||_2^2 + \alpha^2 ||\mathbf{m}||_2^2$$
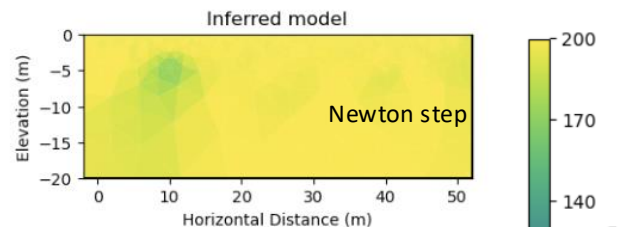
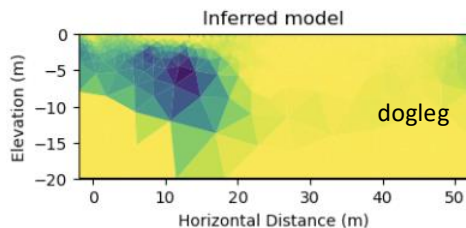## Ensemble methods

Parameter space samples

Sample a target pdf

$$p(\mathbf{m}|\mathbf{d}) = k \times p(\mathbf{d}|\mathbf{m}) \, p(\mathbf{m})$$

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Mineral exploration is about possibilities

Provided data

Electrical resistivity tomography

True model

CoFI - Common **F**ramework for **I**nference

Inferred model — dogleg

Inferred model — Newton step

Inferred model — RAdam

Inferred model — trust-kyrlov
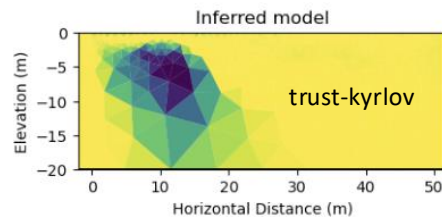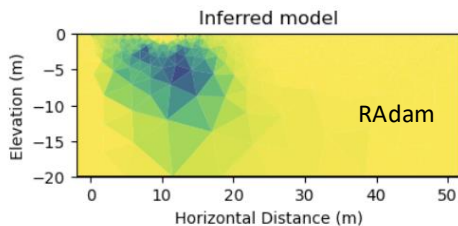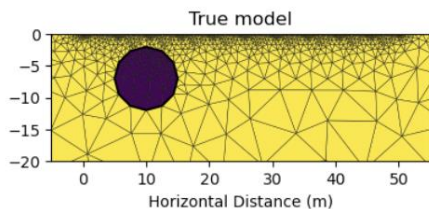
and so is finding an inference method using CoFI…

Momentum based optimizers

Vanilla iterative non-linear optimizers only consider the objective function at the current location

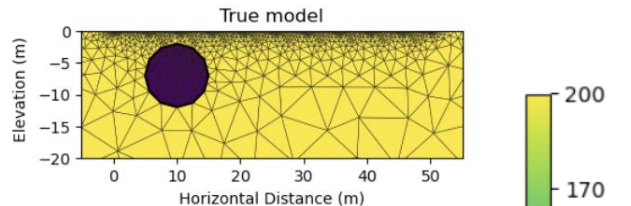Machine learning methods are frequently applied to noisy data

Build inertia into the search direction to overcome local minima

CLASS torch.optim.RAdam(*params*, *lr=0.001*, *betas=(0.9, 0.999)*, *eps=1e-08*, *weight_decay=0*, *decoupled_weight_decay=False*, *, *foreach=None*, *differentiable=False*) [SOURCE]

https://pytorch.org/docs/stable/generated/torch.optim.RAdam.html
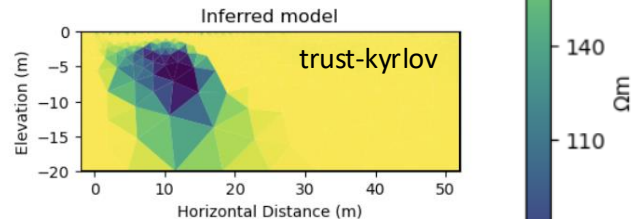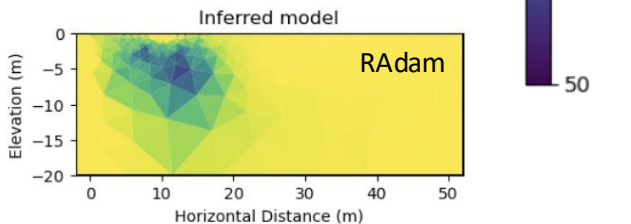
The CoFI explorer
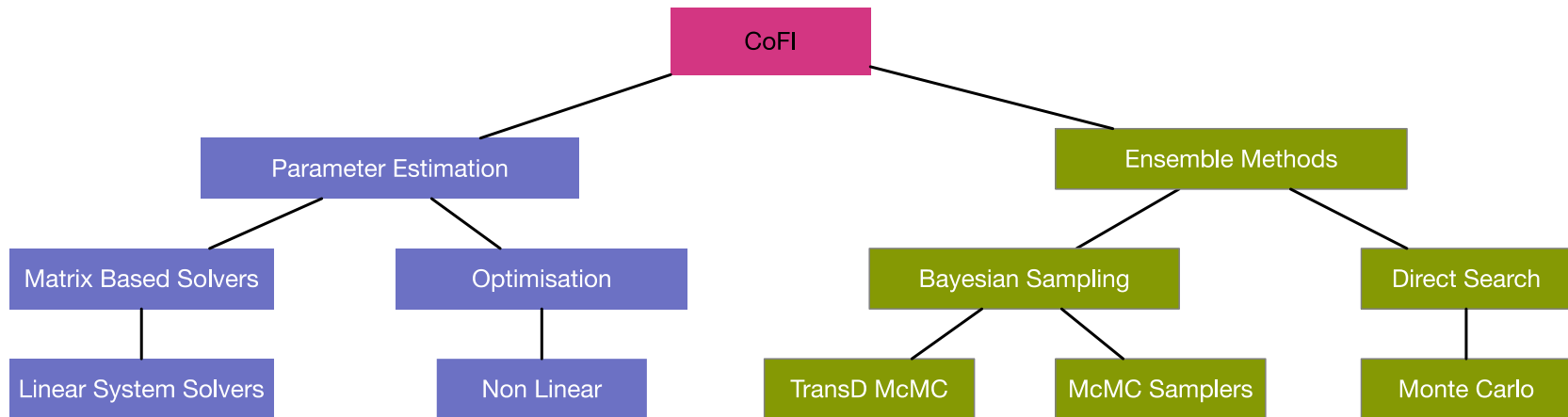
www.inlab.au/inlab-explorer

Build on existing and emerging software packages
Example driven – we only add a method if there is an example that needs it
Findable, accessible, interoperable and reusable software

Capturing an inverse problem

Base Problem

```
inv_problem = BaseProblem()
inv_problem.set_objective( DEFINE ME)
inv_problem.set_jacobian(DEFINE ME)
inv_problem.set_initial_model(DEFINE ME)
```

Jacobian
Residuals
Log Likelihood
…

Inversion Options

```
inv_options = InversionOptions()
inv_options.set_tool("scipy.linalg.lstsq")
```

Proposal Strategy
Convergence Criteria
Number of iterations
…

Inversion

```
inv = Inversion(inv_problem, inv_options)
result = inv.run()
```

An inverse method needs to only access a subset of features of a forward problem

Capturing a rich set of examples

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On the menu

Time	Topic
0830-0840	Welcome and setup
0840-0910	Introduction to CoFI
0910-1000	Interactive session: Linear regression
1000-1030	Morning Refreshments and Trade Exhibition
1030-1130	Inverting for a thin plate target
1130-1200	Questions and Answers

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Take home messages…

What we hope you will take home today:

An understanding what CoFI can do.

Some familiarity with the design and philosophy of CoFI

Cognizance of the avenues to engage with CoFI and InLab

What we hope to take away today:

Priorities: Expanding the methods; the examples, building a community, other?

Wish lists: scalability; real data problems; automatic differentiation…

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CoFI – A **Co**mmon **F**ramework for **I**nference
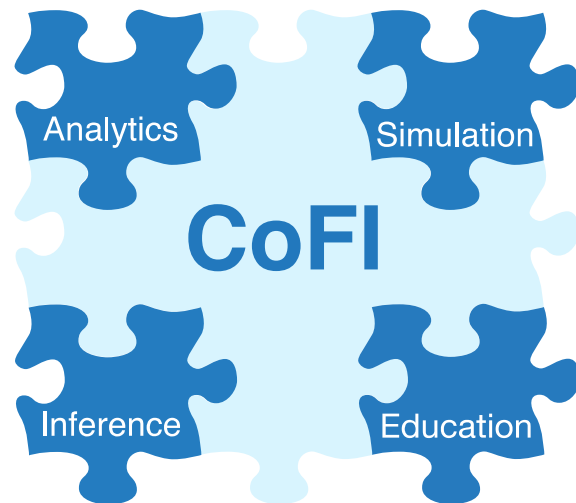
The application domain expert says:

- **What inference methods are suited to my data?**
- **Where can I get access to them? What is required to make them talk to my forward problem/data?**
- **How much work is that for me?**

The research manager says:

- **How can my staff learn about state-of-the-art inference methods**
- **How do we access the expertise?**
- **Can we keep our design options open?**
- **How long will it take?**

The inference specialist says:

- **What other problems can my inference method solve?**
- **Where can I get access to them?**
- **How much work is that for me?**

Analytics

Simulation

CoFI

Inference

Education

www.inlab.au

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