ANALYSIS OF AN ASYMMETRY-AWARE METHOD FOR SINGLE SEISMOMETER FOCAL MECHANISM INVERSION

Summer Research Project Presentation

OVERVIEW

Problem

- An assumed double-couple faulting mechanism can be inferred via inversion given data from one seismometer.
- Inversion should account for simulated relative amplitudes within acceptable range of observed amplitudes based on uncertainties.
- We need an asymmetry-aware model since uncertainties are not homogenous.

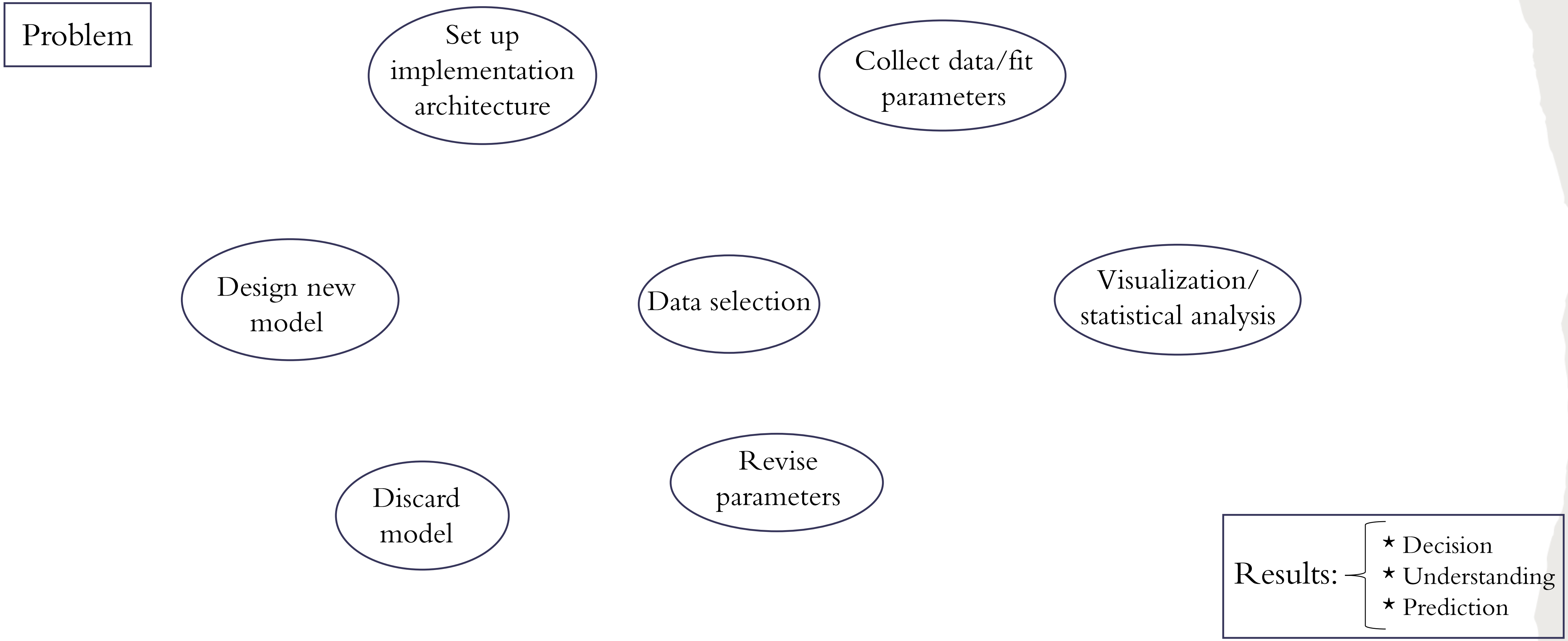
Method & Analysis

- Model based on misfit angle between abstract representation of simulated and observed amplitudes as vectors in 3D space.
- Implement model using computer programming, produce relevant information and visuals for statistical analysis.
- Investigate performance with real world data in single seismometer settings.

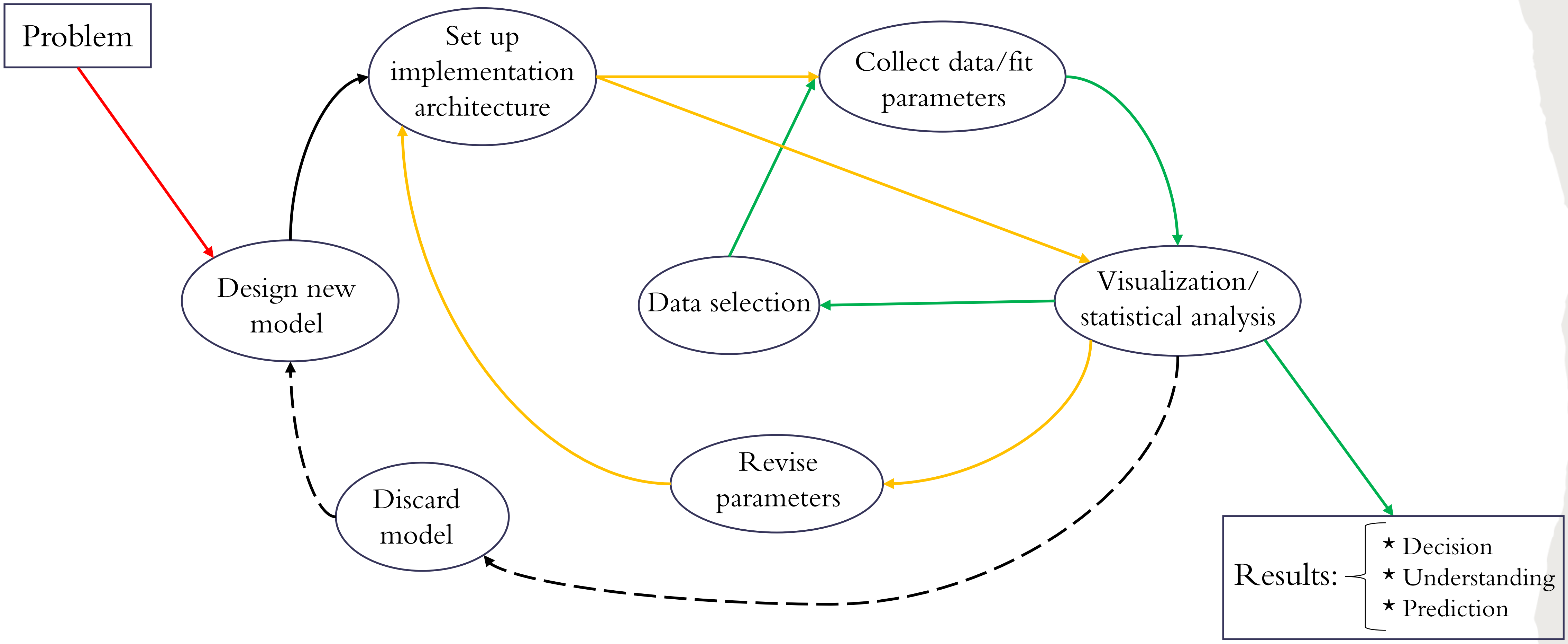
Results

- Reliable focal mechanism inversion.
- An understanding of the capabilities and limitations of this method.
- Deciding under which conditions it should/shouldn’t be used.

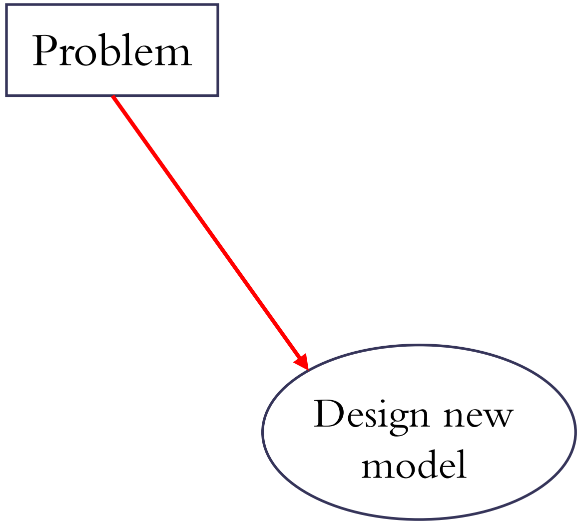
PROJECT STRUCTURE



PROJECT STRUCTURE: ANALYTICAL CYCLE



FOUNDATION



FOUNDATION: LAGRANGIAN OPTIMIZATION

Problem

Design new model

$$\vec{n}_1 = \vec{A}_o \times \vec{A}_s$$

$$\vec{n}_2 = \left[\frac{A_{o.x}}{{U_x}^2}, \frac{A_{o.y}}{{U_y}^2}, \frac{A_{o.z}}{{U_z}^2} \right]$$

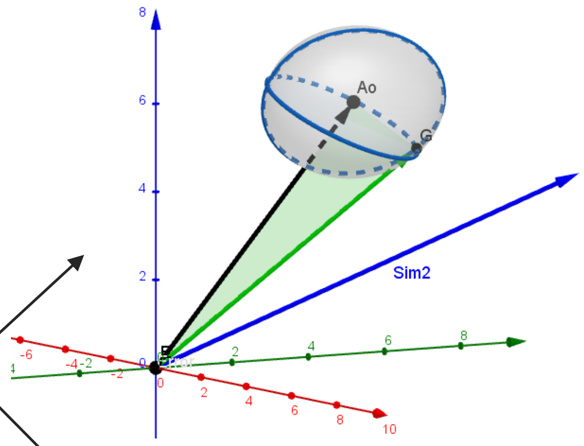
$$\vec{m} = \vec{n}_1 \times \vec{n}_2$$

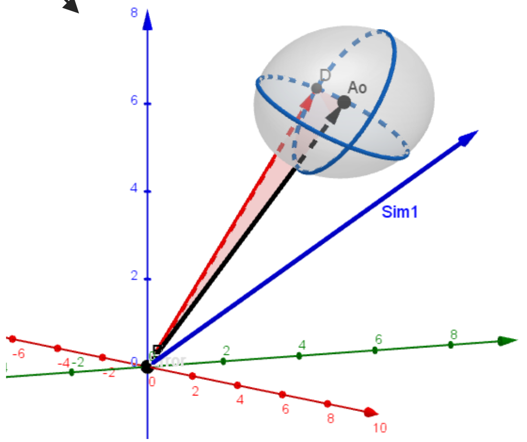
$$\vec{r}(t) = \left(1 - \frac{1}{\vec{n}_2 \cdot \vec{A}_o} \right) + t\vec{m}$$

$$\vec{v} = \left[\frac{m_x}{U_x}, \frac{m_y}{U_y}, \frac{m_z}{U_z} \right]$$

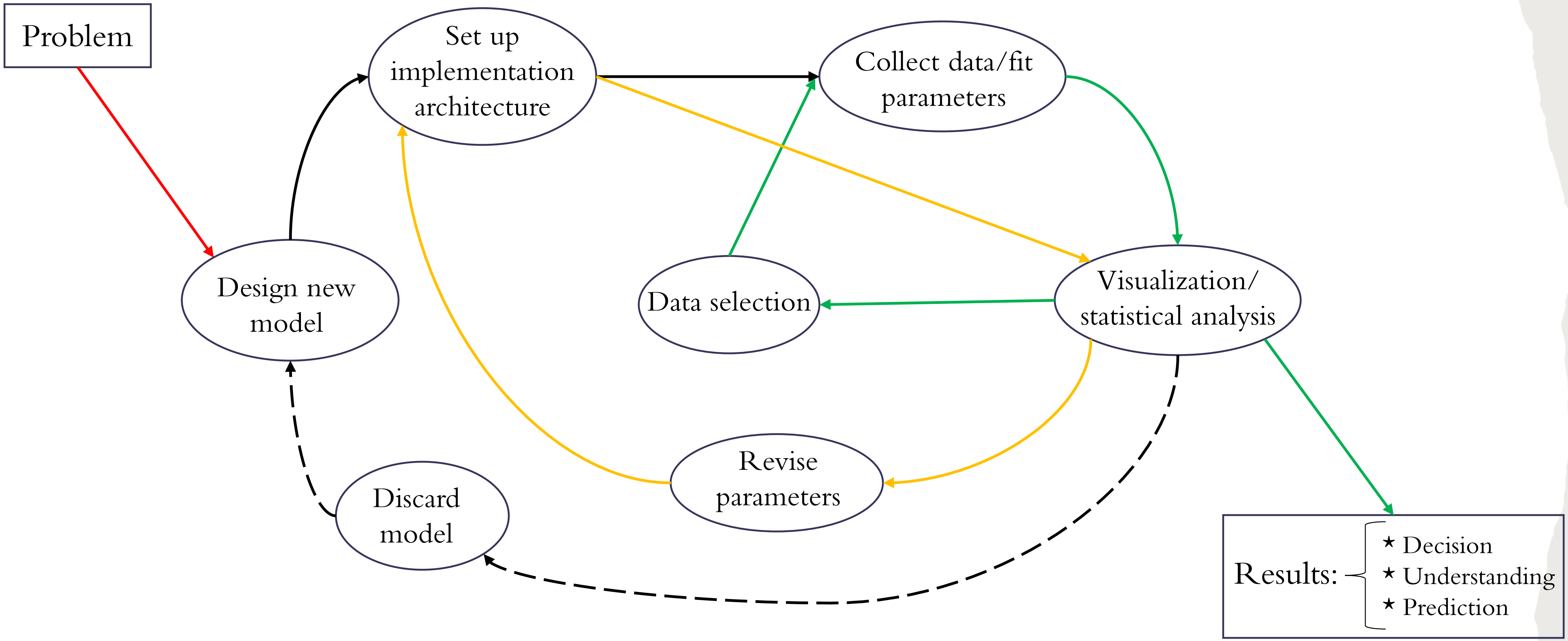
$$(t_1, t_2) = \frac{\left(\frac{\vec{n}_2 \cdot \vec{m}}{\vec{n}_2 \cdot \vec{A}_o} \right) \pm \sqrt{\left(\frac{\vec{n}_2 \cdot \vec{m}}{\vec{n}_2 \cdot \vec{A}_o} \right)^2 + (\vec{v} \cdot \vec{v}) \left(1 - \frac{1}{\vec{n}_2 \cdot \vec{A}_o} \right)}}{\vec{v} \cdot \vec{v}}$$

Asymmetry-aware!

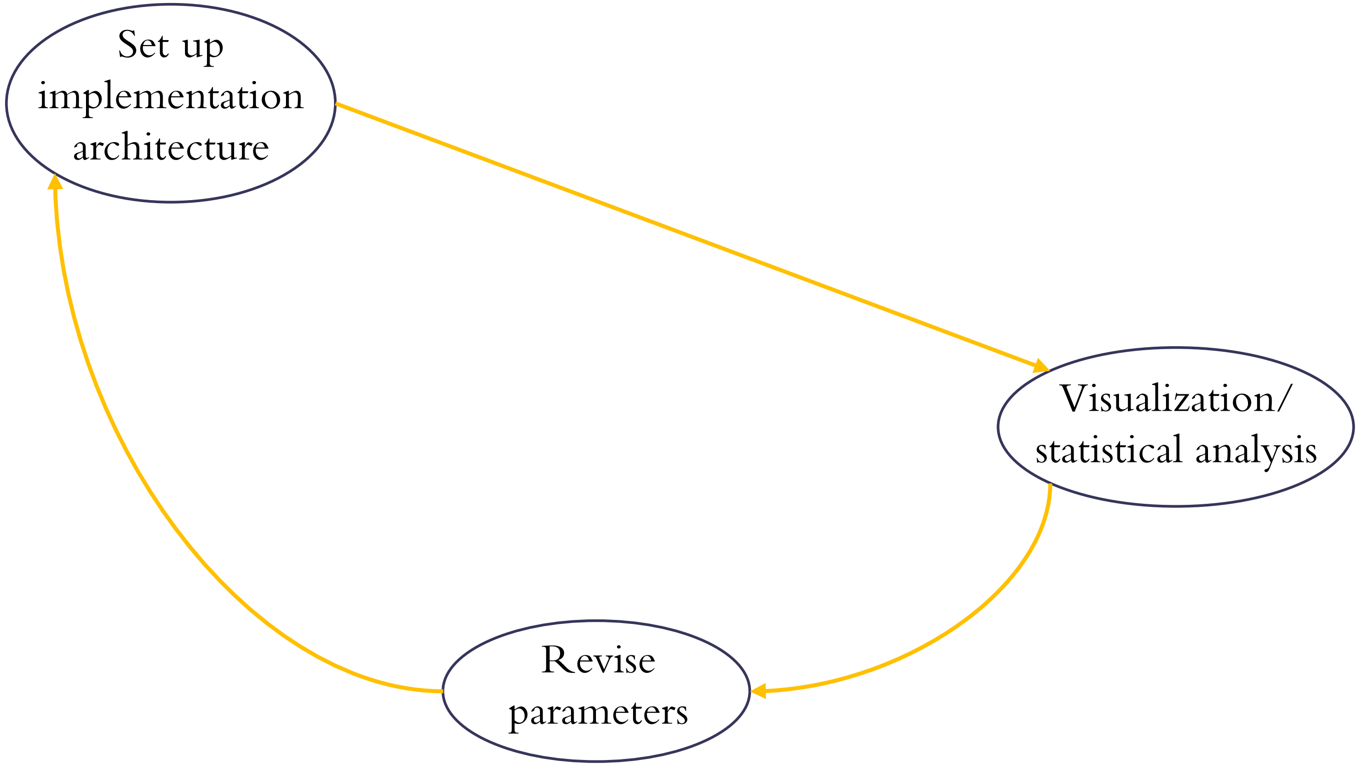




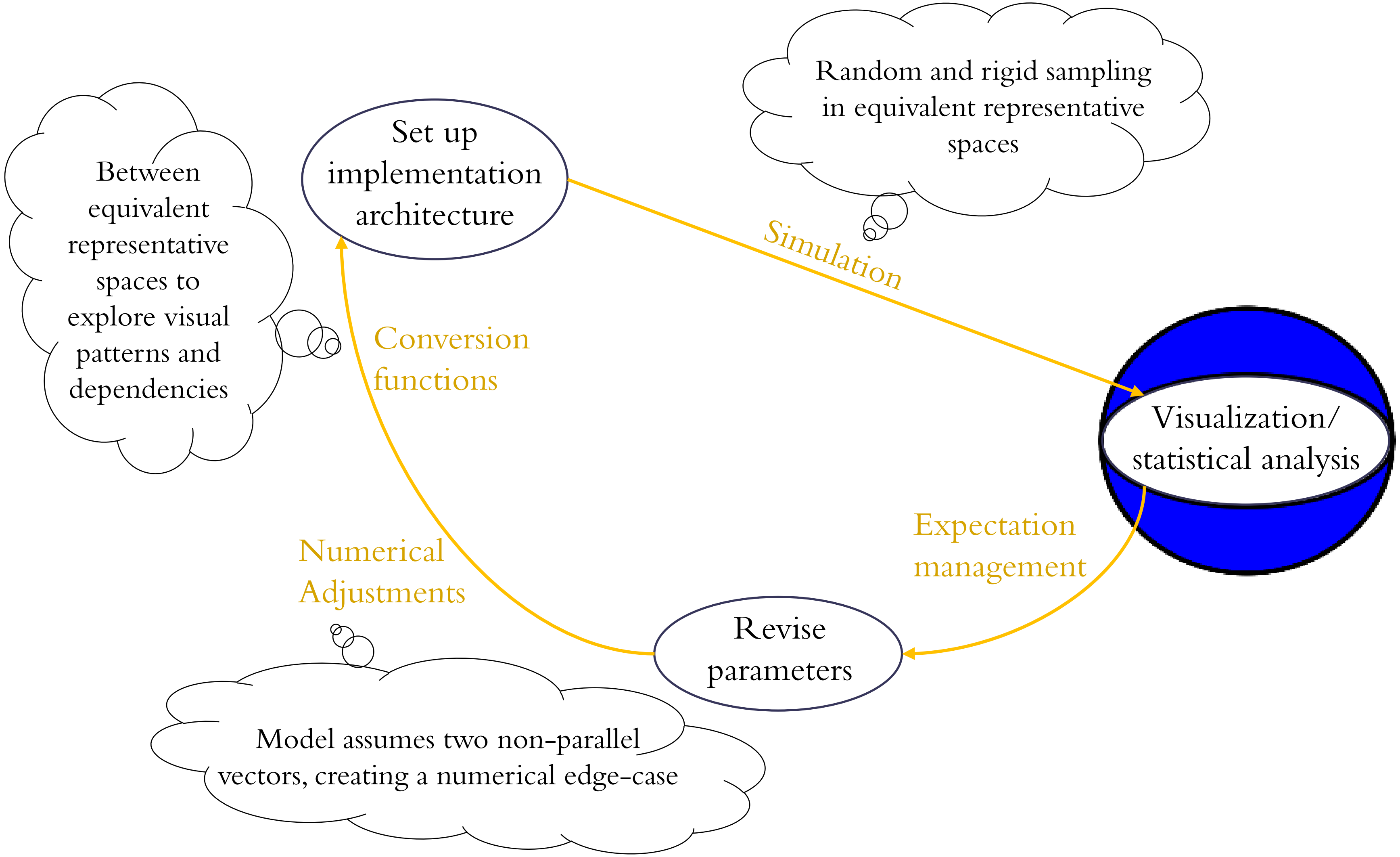
SUMMER FOCUS



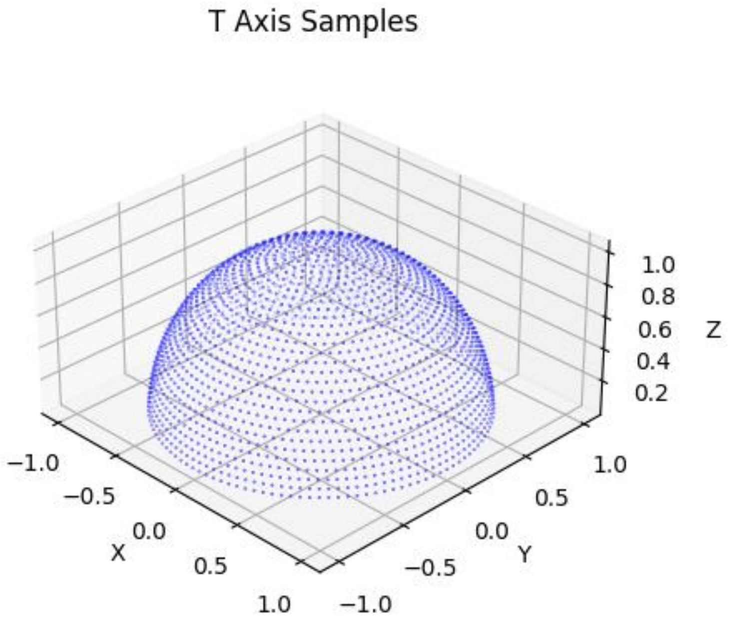
SUMMER FOCUS

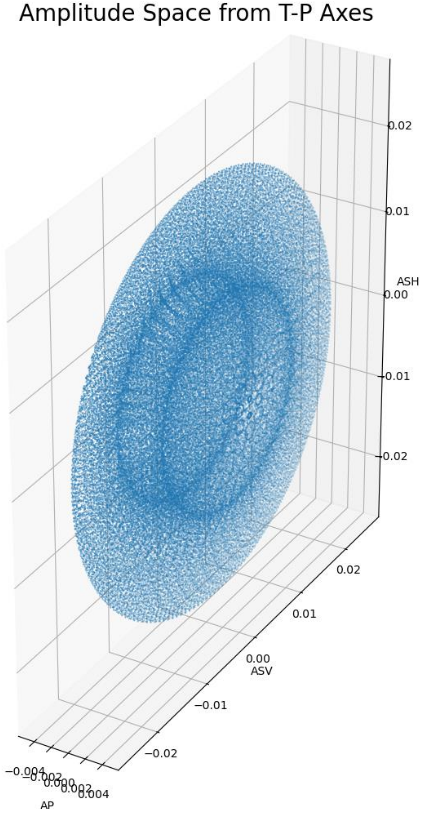


SUMMER FOCUS: PYTHON PROGRAMMING

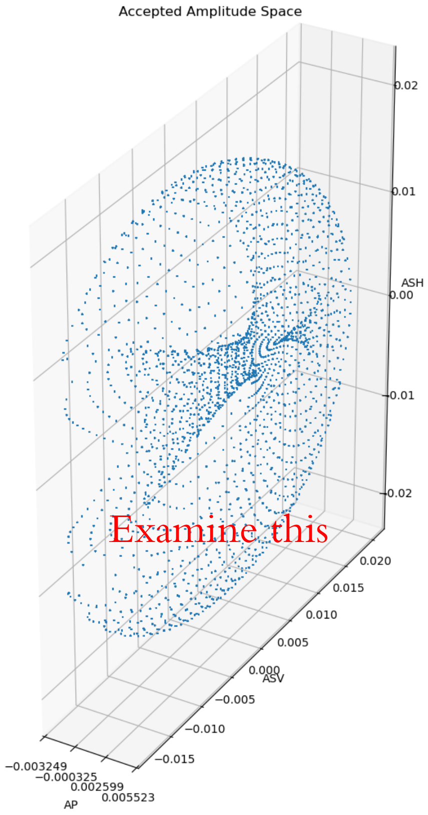


KEY FINDINGS





Relate these

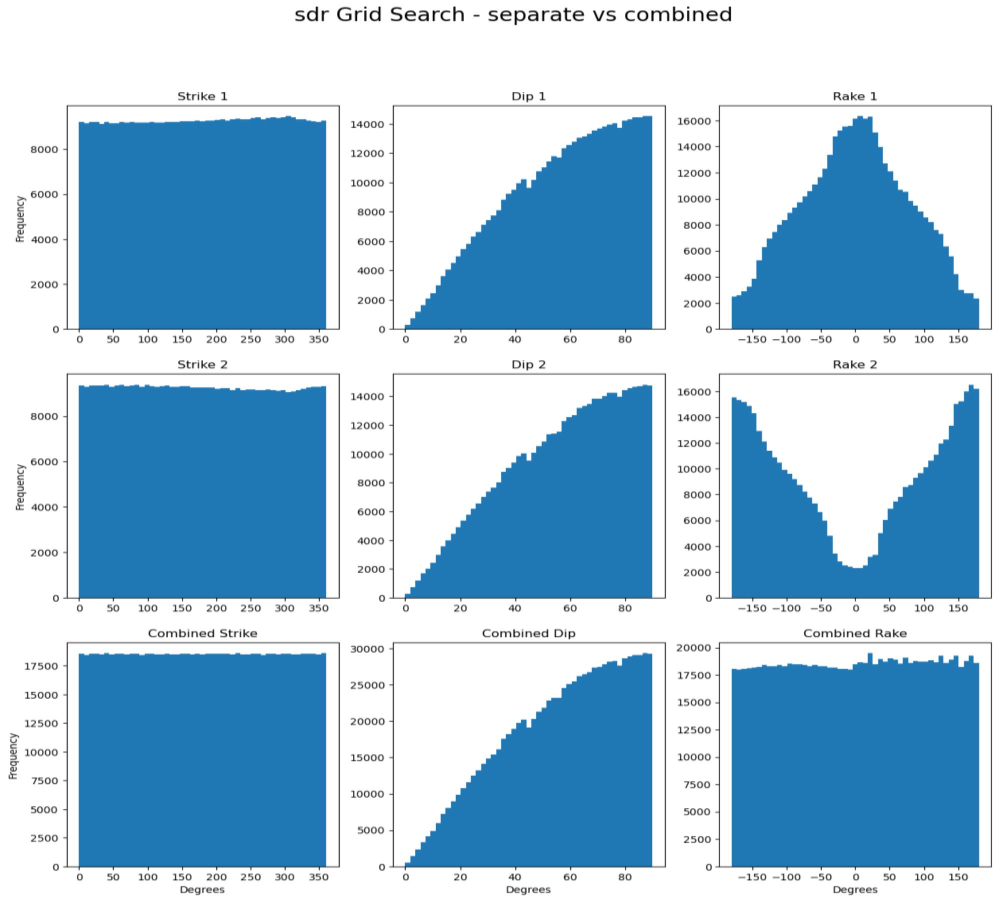


Rigid sampling preferred to narrow analytical focus

The abstract amplitude space is itself an ellipsoid with S-wave amplitudes having the same sample space

Method can perform basic inversion (normal fault inversion displayed)

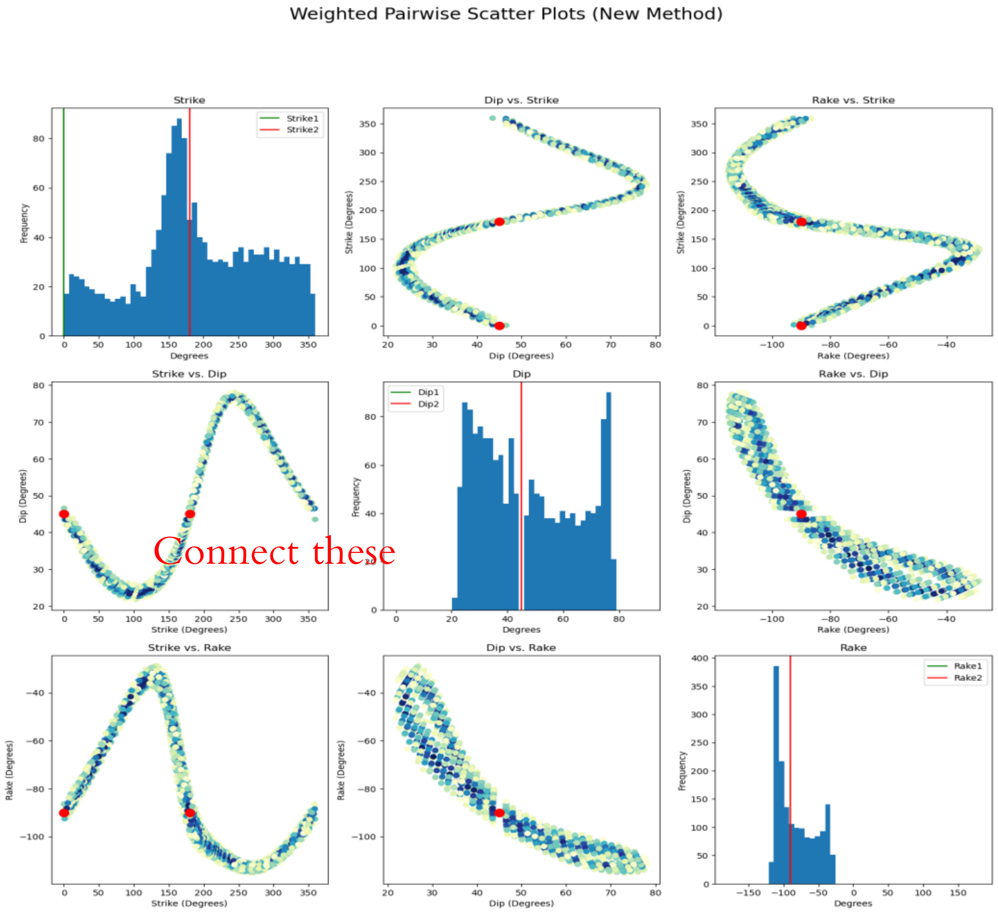
KEY FINDINGS



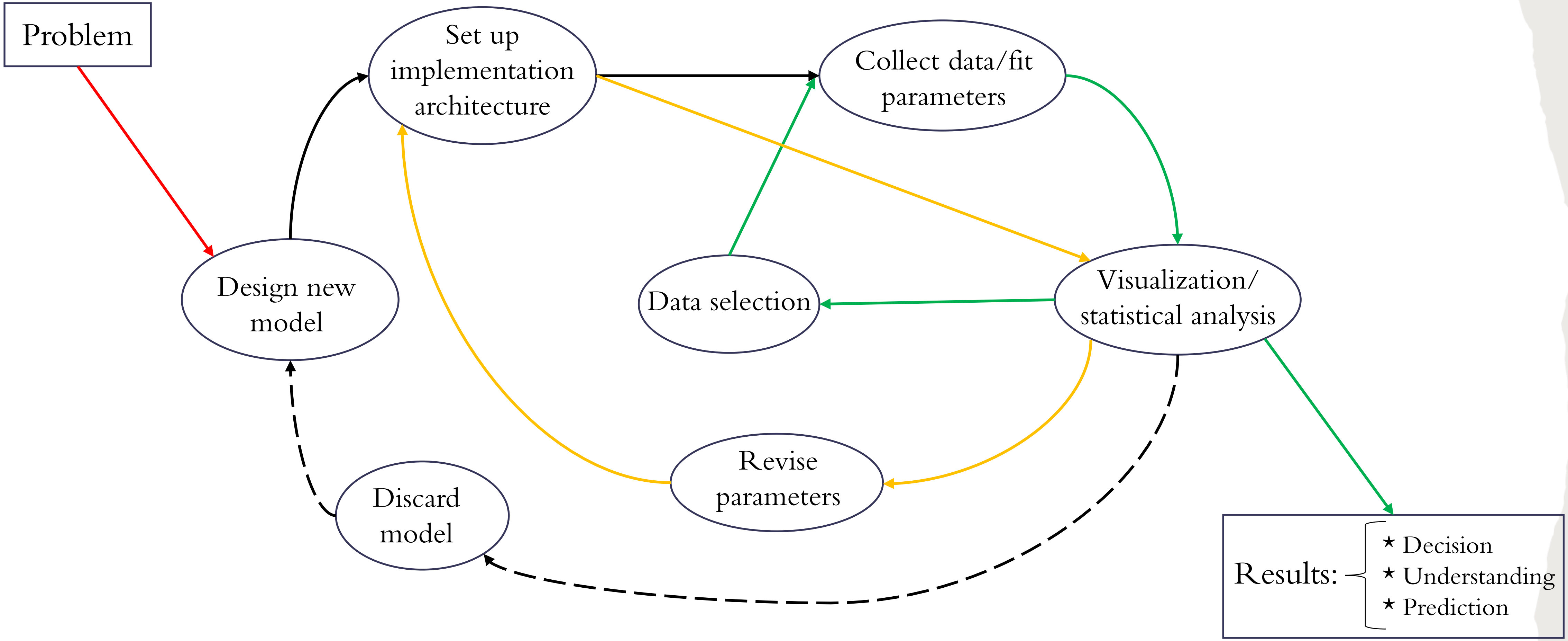
Sinusoidal dip distribution

Rake distribution per fault plane depends on geometry of search algorithm

Method selects focal mechanisms that (so far) have a periodic relationship in strike, dip, rake space

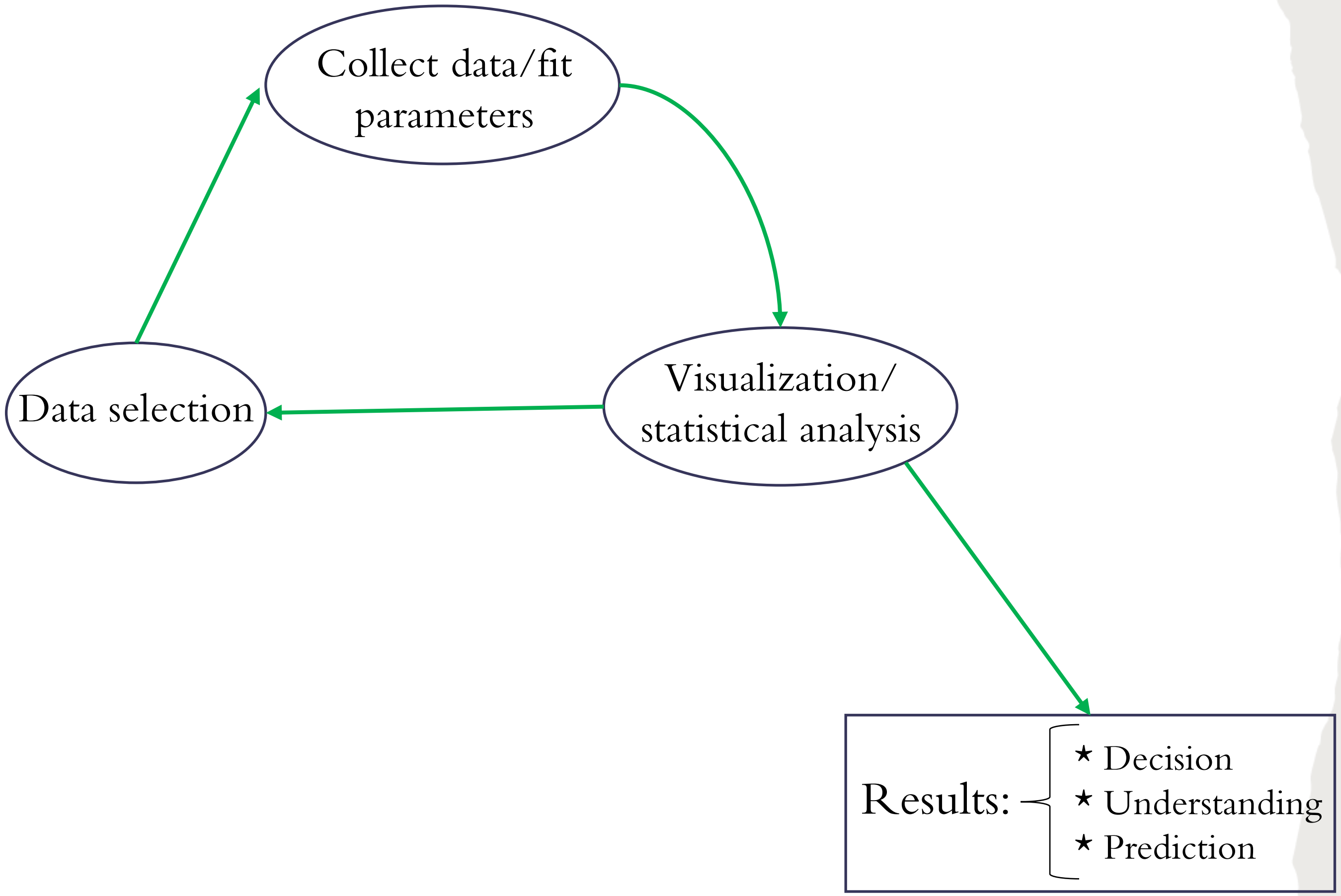


NEXT STEPS



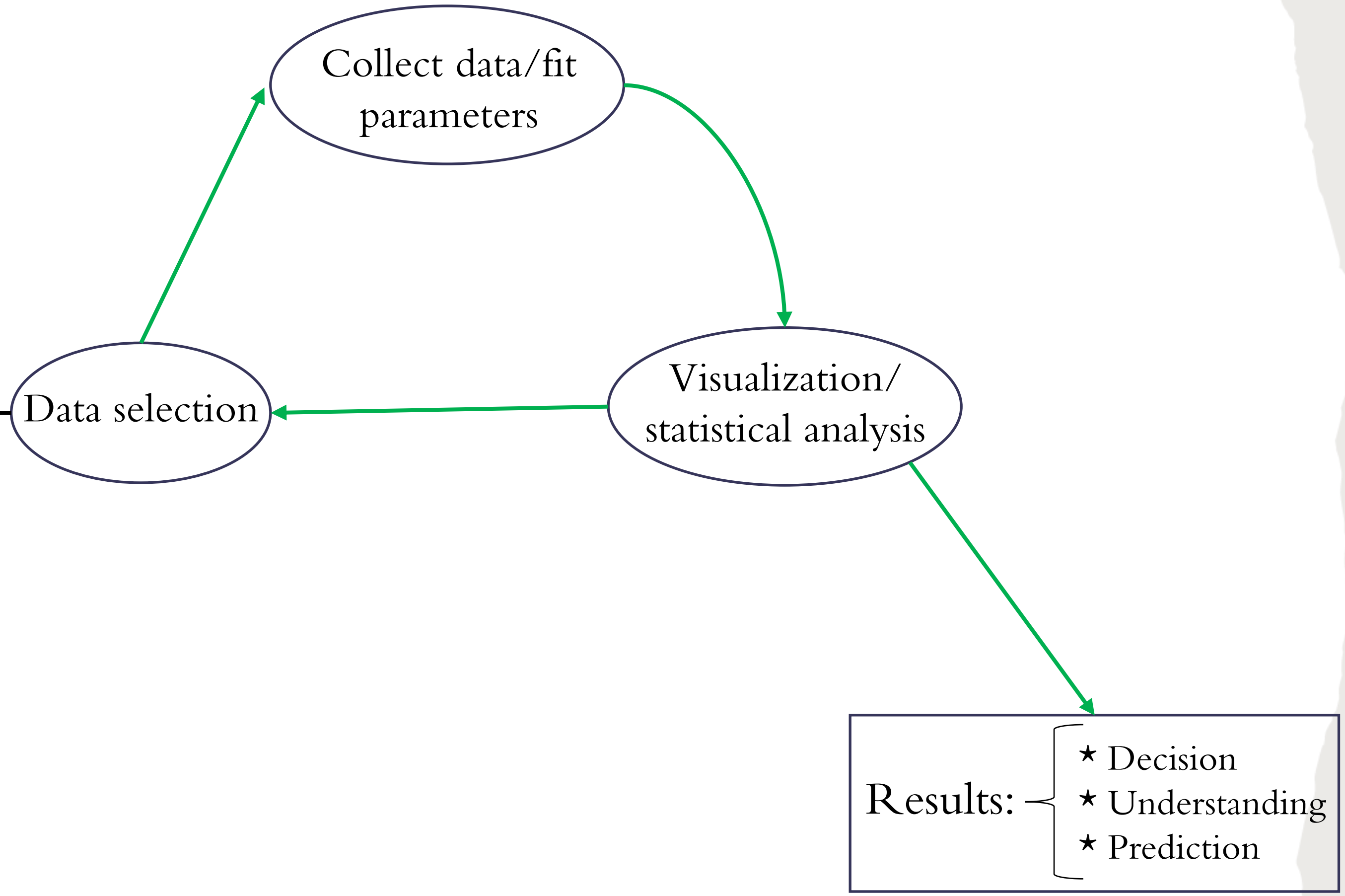
Problem
Set up implementation architecture
Collect data/fit parameters
Design new model
Data selection
Visualization/ statistical analysis
Revise parameters
Discard model
Results:
⋆ Decision
⋆ Understanding
⋆ Prediction

NEXT STEPS


Collect data/fit parameters
Visualization/ statistical analysis
Data selection
Results:
★ Decision
★ Understanding
★ Prediction

NEXT STEPS: CAPABILITIES AND LIMITATIONS

- Exploring visualizations for insights:
  - ⋆ Representative aggregate beachballs
  - ⋆ Ternary diagrams
- Sampling cost-effectively through full range of parameters (focal mechanisms, epicentral distances & depths…)
- More efficient inversions
  - ⋆ Iterative algorithms?
  - ⋆ Stochastic algorithms?
  - ⋆ Genetic algorithms?
- Sensitivity analysis
  - ⋆ Effect of small errors
- Dimensionality reduction
  - ⋆ Effect of collapsing an amplitude dimension
- Uncertainty dependencies
  - ⋆ Analytic derivatives



PENDING QUESTIONS

- How is the approximated version of the inversion algorithm different from the current one?
- Why does the amplitude space have discs at the center?
- Why is the inversion scattered and not a subset? (look at implementation)
- What might we be missing when sampling rigidly over t-p axis space vs strike, dip, rake space?
- What's the most important next step relative to the broad aim of the project?
- Recommended visual representation tools for documentation?