On the Use of the `ubcdiss` Template

by

Johnny Canuck

B. Basket Weaving, University of Illustrious Arts, 1991

M. Silly Walks, Another University, 1994

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Doctor of Philosophy

in

THE FACULTY OF XXX

(Basket Weaving)

The University of British Columbia

(Vancouver)

April 2192

Abstract

This document provides brief instructions for using the `ubcdiss` class to write a University of British Columbias (UBCS)-conformant dissertation in LaTeX. This document is itself written using the `ubcdiss` class and is intended to serve as an example of writing a dissertation in LaTeX. This document has embedded Unique Resource Locators (URLS) and is intended to be viewed using a computer-based Portable Document Format (PDF) reader.

Note: Abstracts should generally try to avoid using acronyms.

Note: at UBC, both the Graduate and Postdoctoral Studies (GPS) Ph.D. defence programme and the Library's online submission system restricts abstracts to 350 words.

Preface

At UBC, a preface may be required. Be sure to check the GPS guidelines as they may have specific content to be included.

Table of Contents

List of Tables

List of Figures

Glossary

This glossary uses the handy `acroynym` package to automatically maintain the glossary. It uses the package's `printonlyused` option to include only those acronyms explicitly referenced in the LaTeX source.

GPS Graduate and Postdoctoral Studies

PDF Portable Document Format

URL Unique Resource Locator, used to describe a means for obtaining some resource on the world wide web

MOF Model Objective Function

Acknowledgments

Thank those people who helped you.

Don’t forget your parents or loved ones.

You may wish to acknowledge your funding sources.

Chapter 1

Introduction

If I have seen farther it is by standing on the shoulders of Giants.
— Sir Isaac Newton (1855)

In all cases these are first guesses at what needs to be in each section more or less detail need to be added.

1.1 What problems

Geophysical inversions, specifically potential fields include formulation of non-regularized inverse problem

1.2 Difficulties with said problems

The standard way to fit a set of parameters to a set of data (especially when they are related by a linear operator) is least squares optimization. This is rendered problematic since, in general, geo-physical inversions are ill-conditioned (define) and undetermined (define) ([1] other sources I'm sure). In specific potential fields are particularly under-determined due to the lack of any depth information in the data.

show some form of problems with forward operator matrix in PF inversion

1.3 Solutions to said difficulties

To mitigate the difficulties presented above an extra term is added to the optimization.

$$\phi = \phi_d + \beta \phi_m \tag{1.1}$$

where ϕ_m is called the Model Objective Function (MOF) or model norm. This ϕ_m can be defined in many ways, following [1]

$$\phi_m(m) = \alpha_s \int (m - m_{ref})^2 dx + \alpha_x \int \left(\frac{d}{dx}(m - m_{ref}) \right)^2 dx \tag{1.2}$$

$$= \alpha_s \|\mathbf{W}_s(m - m_{ref})\|_2^2 + \alpha_x \|\mathbf{W}_x(m - m_{ref})\|_2^2 \tag{1.3}$$

in higher dimensions more smoothness terms can be added. The $\mathbf{W}$ terms contain both the operator (identity for $\mathbf{W}_s$ and derivative for $\mathbf{W}_x$ and other dimensions) and the relative weight each cell or face contributes to the MOF. This gives us several levers to add a-priori information into the inversion.

The MOF allows us to mathematically solve the problem by adding a priori information into the inversion. Namely we assume that the recovered model should be small and smooth. There are times when this is desired but often we have more specific information about the true model that needs to be inserted into the inversion. Luckily the various terms in the MOF allow us to add a significant amount of information is various ways to the inversion.

1.3.1 α coefficients

broad strokes weights the relative importance of the smallness and smoothness in the various directions. can also be thought of as length scales

1.3.2 Reference Models

we don't always want a model to be close to zero. Sometimes it should be close to another constant sometimes we have guesses of the property in some places and want the inversion result to be close to that value

1.3.3 Weighting matrices

much more precise. Can put interfaces in precise locations. Can also force a model towards the reference model where we are more sure

along with the terms in the MOF other parts of the optimization algorithm (may need more info in the optimization) can be used to add information into the inversion

1.3.4 Initial Model

In the optimization we assume that the initial guesse is near enough to the truth that the problem is locally convex. The initial model is important in that way. In an under determined system it also provides a way to push the invesion towards a given result. Often the initial model is simply the reference model, or the reference model shifted slightly to keep it within the bounds

1.3.5 Bounds

we can also set values that each cell of the final model must lie between. This allows for a hard setting of confidence intervals in the physical properties

1.3.6 L_pL_q weights

Finally we can generalize the MOF somewhat. In Equation 1.3 we used L_2 norms as this is a natural norm that promotes a smoothly varying model that is close to the reference model. We do not always want such a model and can change the norm used in the MOF. Lower norms promote more sparsity in whatever measure they are being applied to. This leads to models being more compact (should lowever norms be applied to the smallness term) or more blocky with greater discontinuities (should lower norms be applied to one or more smoothness terms). Non L_2 norms can be applied across the whole MOF or can be applied variably across the model. This allows for placing discontinuities in a given direction but not perfectly placing the location allowing the inversion algorithm more freedom to chose the location itself.

1.4 Forms of A Priori Information

1.4.1 Data

Chapter 2

Case Study #1 El Poma South

In all cases these are first guesses at what needs to be in each section more or less detail need to be added.

2.1 General Overview of El Poma

Two anomalies. North and South. This section discusses the southern anomaly. The next discusses the northern one.

Magnetic Anomaly. Remanent magnetization is clearly present

2.2 Overview of Deposits

2.3 Discussion of the Geophysical Data Given

Magnetics. Missing a corner.

2.4 What Information is Available

Bore Hole -susceptibilities, much lower than the recovered model sue to remanent effects being present

Plan View Geological map -with susceptibility surface samples marked, in addition to surface samples and geological units, we also have a system of thrust faults over top of both anomalies.

Surface Samples -susceptibility, same as marked on map but includes many samples from outside map area as well -also have nine remanences measured with direction and K_n

2.5 Synthetic Model

TODO: Create Model - make iso-surface of Kris's result. Determine property from parametric inversion. show model discuss its creation - magnetization direction

show its fit to the field data

2.6 Blind Inversion of the Synthetic Model

Show results. Discuss how magnetization direction puts anomaly away from actual location

2.7 Determination of Magnetization Dirrection

Correlation of Vertical and Total Gradients of Half RTP field [**?**]

taking core direction from MVI result could also use parametric inversion and MVI sensitivities to provide more constraint.

apply recovered direction to the anomaly direction in MAG3D could apply anomalous dirrection locally to anomaly

2.8 Creation of Constraints

2.8.1 α coefficients

For El Españole (north south fault) we can lower the α_x to allow for greater discontinuity in general in that direction. Cannot account for other faults without rotation objective function.

(show result)

2.8.2 Reference Models

Most work to be done here.

Borehole: provides susceptibilities need to convert into effective susceptibilities. Assuming uniform magnetization direction this is not complicated. Choose a K_n and multiply susceptibility by that (maybe with +1). For MVI I need to apply the dirrection of magnetization as well. Either from the truth of the synth model from direction of the nearest remanent sample or from the bulk rem mag direction. (show reference model) (show result)

Map: geological units have susceptibilities attached. Have to convert into effective susceptibilities. Might extend the map cells down below surface to be less weighted (show reference model) (show result)

Surface Samples: used to make susc values for geological units. Can also be used for reference model directly but this provides less cover of the surface. Perhaps use surface samples in white region instead of just applying nothing. (show reference model) (show combined map and SS reference model) (show result)

(show Combined result)

2.8.3 Weighting matrices

smallness: using some measure of confidence in the measures decrease in cells with reference model specified to force the result to approximate the reference model. In case that map is extended down I will lower the W_s as model cells are further below the surface. (show smallness weight model) (show result, compare to result without)

smoothness: to spread the model values away from where they are specified I can increase the smoothness weights in the vicinity of cells with specified reference models. (show face weight model) (show result, compare to result without) The other application of smoothness weights is to allow discontinuities on the faults (perhaps with increased smoothing on either side of the fault). Need to experiment with orientations of the faults. (show result)

(show Combined result)

2.8.4 Bounds

Also useful for forcing model values to be near the specified reference model while allowing for uncertainty in our phys prop value (show result)

2.8.5 L_pL_q weights

allows the more fuzzy placement of faults. By rotating the MOF we can place them in arbitrary directions. The trouble is having more than one fault in more than one orientation. Can't currently apply to MVI inversions, can still apply on MAG3D inversions (show result)

Need to determine if showing the field example is worthwhile at this point and how to bring it into the narrative

Chapter 3

Case Study #2 El Poma North

In all cases these are first guesses at what needs to be in each section more or less detail need to be added.

3.1 Overview of Deposits

Two anomalies. North and South. This section discusses the northern anomaly.

Magnetic Anomaly. Remanent magnetization is clearly present

3.2 Discussion of the Geophysical Data Given

Magnetics. Much better coverage than in south.

3.3 What Information is Available

all same as with south. Different configurations. Map shows anomalous unit dirrectly above perceived anomaly, We have a borehole right through anomaly. Less surface sample density.

3.4 Synthetic Model

TODO: Create Model - make iso-surface from best guess inversion. Use parametric inversion to add properties. show model discuss its creation - magnetization direction show its fit to the field data

3.5 Blind Inversion of the Synthetic Model

Show results. Discuss how magnetization direction puts anomaly away from actual location. Assuming that it does (I expect that it will).

3.6 Determination of Magnetization Dirrection

Correlation of Vertical and Total Gradients of Half RTP field [**?**]

taking core direction from MVI result could also use parametric inversion and MVI sensitivities to provide more constraint.

apply recovered direction to the anomaly direction in MAG3D could apply anomalous dirrection locally to anomaly

3.7 Creation of Constraints

3.7.1 α coefficients

not much with alphas to be done here given that we don't expect discontinuity in any one particular dirrection.

3.7.2 Reference Models

Most work to be done here.

Borehole: provides susceptibilities need to convert into effective susceptibilities. Assuming uniform magnetization direction this is not complicated. Choose a K_n and multiply susceptibility by that (maybe with +1). For MVI I need to apply the dirrection of magnetization as well. Either from the truth of the synth model from direction of the nearest remanent sample or from the bulk rem mag direction. (show reference model) (show result)

Map: geological units have susceptibilities attached. Have to convert into effective susceptibilities. Might extend the map cells down below surface to be less weighted (show reference model) (show result)

Surface Samples: used to make susc values for geological units. Can also be used for reference model directly but this provides less cover of the surface. Perhaps use surface samples in white region instead of just applying nothing. (show reference model) (show combined map and SS reference model) (show result)

(show Combined result)

3.7.3 Weighting matrices

smallness: using some measure of confidence in the measures decrease in cells with reference model specified to force the result to approximate the reference model. In case that map is extended down I will lower the W_s as model cells are further below the surface. (show smallness weight model) (show result, compare to result without)

smoothness: to spread the model values away from where they are specified I can increase the smoothness weights in the vicinity of cells with specified reference models. (show face weight model) (show result, compare to result without) much less in the way of fault dirrectly over anomaly. Perhaps with dipping faults there will be a constraining plane. Only have to factor in El Deleite fault.

(show Combined result)

3.7.4 Bounds

Also useful for forcing model values to be near the specified reference model while allowing for uncertainty in our phys prop value (show result)

3.7.5 L_pL_q weights

allows the more fuzzy placement of faults. By rotating the MOF we can place them in arbitrary directions. The trouble is having more than one fault in more than one orientation. Can't currently apply to MVI inversions, can still apply on MAG3D inversions

Perhaps with dipping faults there will be a constraining plane. Only have to factor in El Deleite fault. (show result)

Need to determine if showing the field example is worthwhile at this point and how to bring it into the narrative

MUCH similarity. perhaps this should not be its own section. Need to run some of the data to determine where the northern anomaly is different from south.

Chapter 4

Case Study #3 TKC

In all cases these are first guesses at what needs to be in each section more or less detail need to be added.

4.1 Overview of Deposits

Kimberlite Complex Two anomalies, focusing on the southern one (DO27)

Magnetic Anomaly. Remanent magnetization is likely present but largely in the dirrection of the earth's field Density Anomaly.

4.2 Discussion of the Geophysical Data Given

Magnetics. Three different surveys
Gravity: Ground mag (of usable but dubious quality), Gravity Gradiometry airborne data

much EM as well, outside the scope of this Master's Thesis

4.3 What Information is Available

Great deal of borehole data with facies at each depth We also have Phys Props at various points along the holes. We can either mean these across the facies or take the value of each facies that the specially nearest the the measured result.

From the borehole data we also have created a surface model of each of the units again from the borehole data, we have graphical cross section maps

4.4 Synthetic Model

TODO: Create Model - Already mostly done - we have a surface from the borehole data and we can use the parametric inversion to assign the properties. show model discuss its creation - magnetization direction

show its fit to the field data

4.5 Blind Inversion of the Synthetic Model

Show results. show how model is insufficiently compact and over estimates the amount of kimberlite

4.6 Determination of Magnetization Dirrection

Correlation of Vertical and Total Gradients of Half RTP field [**?**]

taking core direction from MVI result

apply recovered direction to the anomaly direction in MAG3D could also use parametric inversion and MVI sensitivities to provide more constraint.

could apply anomalous dirrection locally to anomaly

In any case the result will be very similar to the earth's field in the location

4.7 Creation of Constraints

4.7.1 α coefficients

not much with alphas to be done here given that we don't expect discontinuity in any one particular dirrection.

4.7.2 Reference Models

Most work to be done here.

We can create a reference model from the phys prop results from the borehole data. Perhaps we should only use some of the boreholes so that we have a more realistic amount of information than in a fully drilled example. We have two ways of applying phys prop measures to inversion and might use both. Also using K_ns to improve degree of fit between phys prop measures and effective susc recovered properties (show reference model) (show result)

with sufficient boreholes we could make a incorrect surface that approximates the "true" model used. Use this with parametric inversion for reference model (show reference model) (show result)

using clustering between density and mag create clusters, populate each cluster with parametric inversion and use as reference (show reference model) (show result)

use cross section from [**?**] perhaps extend away from line and down weight (show reference model) (show result)

(show Combined result)

4.7.3 Weighting matrices

smallness: using some measure of confidence in the measures decrease in cells with reference model specified to force the result to approximate the reference model. In case the cross section is extended down I will lower the W_s as model cells are further away from the cross section (show smallness weight model) (show result, compare to result without)

smoothness: to spread the model values away from where they are specified I can increase the smoothness weights in the vicinity of cells with specified reference models. (show face weight model)

with sufficient boreholes we could make a incorrect surface that approximates the "true" model used. Use this with parametric inversion for reference mode,l put lower weights along this surface. (show face weight model)

using clustering between density and mag create clusters, populate each cluster with parametric inversion and put low weights on the interfaces. (show result)

(show result, compare to result without)

(show Combined result)

4.7.4 Bounds

Also useful for forcing model values to be near the specified reference model while allowing for uncertainty in our phys prop value. Since we have more statistical info on the (show result)

4.7.5 $L_p L_q$ weights

can use these to force a blocky model in some directions. Force the shape of a pipe. (show result)

Need to determine if showing the field example is worthwhile at this point and how to bring it into the narrative

Bibliography

[1] D. W. Oldenburg and Y. Li. Inversion for applied geophysics: A tutorial. *Investigations in geophysics*, 13:89–150, 2005. → pages 1, 2

Appendix A

Supporting Materials

This would be any supporting material not central to the dissertation. For example:

- additional details of methodology and/or data;
- diagrams of specialized equipment developed.;
- copies of questionnaires and survey instruments.