# Introduction to Work in Progress

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**Abstract**

A description of the problems I am working on and an index to the documents in which that work is progressing.

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# Contents

# 1 Introduction

The documents described here form a collection bound primarily by the technologies which have been used to produce them, and consist of documents which include formal material in Higher Order Logic processed by ProofPower and which are prepared using LaTeXand delivered in PDF. They are all incomplete, and show me in sceptical mode (i.e. seeking knowledge, with uncertain results). Gradually however, these attempts have become more substantial, and ongoing work is now conceived of as falling in one substantial project in formal philosophy.

As well as an informal overview, this document contains abstracts from each document.

For the record, some information about the various earlier materials is retained.

## 1.1 Central Themes

The work is conceived of as a continuation of the ideas and programmes most particularly of Leibniz and Carnap. The Leibniz connection is most conspicuous in the use of mechanical support for reasoning in formal notations, in the ideals of a universal characteristic and a calculus ratiocinator.

Apart from those important connections the work is more aligned to positivism and Rudolf Carnap than to rationalism and Leibniz.

## 1.2 Active Threads

My thinking now runs primarily along two lines.

The first is methodological, and the second foundational.

**Methodological** I am beginning to find ways of applying mechanised formal methods to problems in philosophy, even to philosophical exegesis. In this it is apparent that 'shallow embedding' is a key technique. This trend is exemplified in [9, 16, **?**, **?**].

I would like to give a good account of the methods used in these documents, together with any issues which arise in giving the philosophical underpinnings for the methods.

**Foundational** There is a foundational thread, which though not wholly disconnected from the methodological one, has its own independent motivation. This has two heads. The most active of these is the search for suitable non-well-founded foundation for use in mechanised applications of formal methods. The point at which this is moving forward is in the work directed towards an illative lambda-calculus in [10].

A subsidiary one, recognising that consistency strength is better derived from well-founded foundations, is concerned with the semantics of well-founded set theory. My ideas in this area have not been formally treated and are not well documented.

## 1.3 Earlier Work

Some of the problems are themselves inherently unformalisable, and so the application of formal methods is expected to yield only incomplete models. The underlying methodological thesis is that even problems which cannot be formally modelled may be illuminated by the study of formalisable near neighbours. This is one way of looking at some of the work which takes place in set theory at present, though set theorists may not look at their work in that way. No originality is claimed for this approach to philosophy.

The philosophical objectives may further be described as:

1. Something rather vague about semantics, one element of which is a certain kind of analysis of the concept of analyticity.
2. Concrete ontology.
3. Abstract ontology.
4. X-Logic.

**Semantics** On the concept of analyticity the study of which is represented here only by the empty shell of one document [26], I shall say no more at present.

The main thrust of my interest in semantics is in the foundations of abstract semantics. For me this is the semantics of set theory, and my approach to this topic is through the study of membership structures [25], also scarcely begun.

The work I have done in historical exegesis is looking like analysis by shallow embedding (a kind of semantic technique) and in my cogitations about how to provide some description of the languages, methods and tools for a philosophical audience it has come to seem a good idea to present HOL in some detail particularly emphasising its merits for the purposes of doing things like shallow embeddings. This has given me motivation for a document [17] not yet off the starting blocks in which an exposition of HOL starting from Church's 1940 paper [3] is combined with an exposition of how good it is for doing a certain kind of semantics.

The notion of proposition is becoming more important to me, perhaps even central to the theoretical philosophy, and the proposition is a semantic entity, but this I think will be mainly discussed under the heading 'X-Logic'.

**Concrete Ontology** Concrete ontology is concerned with what can be known about what concrete entities there are in the Universe. My interest in this began when I attempted to produce an example of how to formalise a scientific theory, and I began to be interested in the metaphysical problems which arise in the course of attempting to formalise fundamental laws of physics. My results of my failed attempts to formalise Newtonian physics are to be found in [15]. I started this intent to minimise my involvement in the underlying mathematics, but was provoked into attempting a more serious approach to the mathematics by Rob Arthan, who started for me the work on differential geometry which can now be found in [1].

My present feeling is that this is an interesting area but one in which I may not be able to make enough progress to be worthwhile. If time were no obstacle my inclination now would be to approach the problem via the theory of general relativity, in particular via formalisation of aspects of [4], supported by a development of differential geometry following reasonably closely chapter 2 of that book.

**Abstract Ontology** The question what can be known about what abstract objects do or may exist was to be addressed primarily through the formal study of membership structures [25], and at present seems the domain most likely to receive my serious attention. However, this area too is hardly begun, and scarcely progressing, because of various matters which seem to me to require attention before this work can have much hope of success. Various other work on set theory is now present, some of it making some use of the material on membership structure (but not much).

There are now quite a few documents on non-well founded set theory, which form a chronological sequence of work which I began in the autumn 2006 and continued (with some interruptions) through to the autumn of 2008. This began with some exploratory work on the formalisation of NF and NFU in HOL in [30], an educational exercise. This lead me to experiment with non-well-founded ontologies more generally and directly without using NF. There is a document on this here, [31] but it doesn't get anywhere because I switched to Isabelle and the fullest formal treatment of that topic is therefore elsewhere [5] with an informal discussion here [6]. I gave two talks on Poly-sets at the Centre for Mathematical Sciences in Cambridge in 2007, the first at one of Thomas Forster's set theory seminars and the second at the NF anniversary workshop shortly after (not quite the same talk) overheads [7] and notes [8] are on-line. These talks present the Poly-sets and also speculate about the approach which I was had in mind to follow and which I did indeed spend about a year (elapsed) on from autumn 2007 to autumn 2008.

This more radical approach to non-well-founded set theory may be found in the documents [31, 21, 22, 23]. This now represent my most substantial piece of research in the foundations of mathematics, but has been suspended pro-tem. The four documents represent a series of four steps in evolving the ideas, primarily simplifications intended to make reasoning about them tractable. For the technical content you can ignore the first three and go straight to the last, all four are I believe logically independent. However, there are probably better informal accounts of what I am trying to do in the earlier document(s), I must move some of them across to the later document.

The culmination was actually an impasse (unsolved problem) on a sufficient condition for extensionality in the interpretations of set theory which are obtained by the method. I had an intuitively plausible criterion and a plan for the proof, I spent considerable time developing the proof, and ended up with a gap which I could not close. I have no definite opinion about whether the conjecture I sought to prove is true, I have been unable to settle the matter either way (though I am still inclined to think it true, I have neither found how to fill in the gap in the proof, nor found a counterargument).

I also have a document on category theory [13] which may as well be mentioned here, though its motivation is not philosophical, except insofar as it connects (which at present it does not) with my lucubrations on categorical foundation systems. There is now a properly foundational exercise in formal category theory in [12], based on the work on NFU in [30]. Its not much good, not only does it not get very far, but I believe I was trying to work out if co-induction would help. I don't think it does, but I never actually properly understood it. In fact the only bit of category theory related foundational work of mine which is worth looking at, if only for its entertainment value) is elsewhere written in XML (Category Theoretic Foundation Systems). I have also started some work on Universal Algebra which was done to support the development of Lattice theory for a new version of X-Logic, and am beginning to try Category theory as based on this theory (though it is not strictly an algebra in the intended sense). This version of category theory is intended to be used in exploring Goguen's work on institutions and further developments along those lines for X-Logic. Most of the algebraic and categorical material is abstract but is not ontological (in the sense I intended for this paragraph).

There is also a foray into Conrad's surreal ontology in "Surreal Geometric Analysis" [33]. This was started when for a short time I thought it might be worth using surreal numbers for the formalisation of the theory of relativity because I thought it might make the handling of singularities nicer. Since I didn't get very far, the interest such as it is in the material present is that there is an attempt at an axiomatisation of the surreal numbers independently of set theory. The idea was to construct this in set theory, but the end result would be to make a set-free axiomatisation of surreals into a proper axiomatic foundation for mathematics (at least technically).

**X-Logic** This is represented at present by one document of formal models [14].

### 1.4 Supporting Theories and Tools

In all this formal work material progress depends upon developments in various enabling technologies not themselves of direct philosophical interest. Like everything else in sight this work is all experimental and incomplete. In these matters, if a problem can be avoided it should be, so one way of improving my treatment of a problem here is to find a way to approach the target applications which does not depend upon the proposed technology. The most obvious candidate here is some of all of the material on inductive definitions.

The supporting theories and tools are, for concrete ontology:

1. differential geometry [1] [this material is obsolescent, being displaced by an approach based on geometric algebra, under development by Rob Arthan]

And for abstract ontology:

1. inductive and co-inductive definitions [20, 19]
2. well-founded relations [2]
3. set theory [18]

And more generally:

- Miscellaneous theory supplements and tactics [28, 27]
- Inference by chaining and supporting materials [27, 34, 11]
- Another collection of Miscellanea which depend upon set theory [29]

### 1.5 ProofPower

The documents in this series all make use of ProofPower. This determines the language in which formal content is expressed (which is ProofPower-HOL).

The there are several (incomplete) documents about ProofPower [35, 32, 24], all produced in the course of co-authoring with Rob Arthan an article for the BCS-FACS newsletter. I also have something in mind on HOL and its use in semantics for which a document has been created, but I have not yet come to a definite idea about how this should be done [17].

# 2 Abstracts

## 2.1 Metaphysical Positivism

Formal models of aspects of Metaphysical Positivism

## 2.2 The Formalisation of Physics

This document provides an example illustrating a method of formalising physical theories, together with a discussion of some aspects of *semantic positivism*.

## 2.3 Differential Geometry

The theory of real vector spaces, norms and derivatives of functions between normed vector spaces as required for formal modelling of some physical theories.

## 2.4 Membership Structures

A queer way of doing set theory in HOL (together with some queer reasons for doing it that way).

## 2.5 Well Founded Relations and Recursion

Fixed points, well founded relations and a recursion theorem.

## 2.6 Miscellanea

This document contains things used by my other theories which do not particularly belong in them. Definitions or theorems which arguably belong in a theory already produced by someone else.

## 2.7 Inductive and Co-inductive Definitions in ProofPower

Systematic facilities for a range of different kinds of inductive and co-inductive definitions of sets and types in ProofPower HOL.

## 2.8 Illustrations of (Co-)Inductive Definitions

This document provides examples of the use of the facilities provided in t007.doc.

## 2.9 Well-orderings and Well-foundedness

This document consists of two parts. The first is a theory of well-orderings prepared by Rob Arthan for possible inclusion in the ProofPower theory of ordered sets. The second is material on well-foundedness, mainly consisting in the proof of the recursion theorem which is needed for consistency proofs of definitions by transfinite recursion respecting (if that's the right term) some well founded relationship.

### 2.10 Miscellaneous Tactics

Several structures providing tactics, tacticals, etc. for theories, forward chaining, backward chaining, theory trawling et.al.

### 2.11 Unifying and Antiunifying Type and Term Nets

Theorem proving in ProofPower is heavily based on rewriting which is supported by term nets which partially match the rewriting rules against target terms. To provide a higher level of automation using unification, closer to the power of modern predicate calculus automation present in other implementations of HOL term nets which unify rather than match, and which also produce antiunifiers have been considered here. This is mainly design, and though there is a very crude implementation, this is for evaluation only and would not deliver reasonable performance.

### 2.12 Backward Chaining

This document provides facilities for automatic reasoning based on backward chaining. They are intended to be similar in capability to refutation proof procedures such as resolution or semantic tableau, but in order to fit in better with interactive proof in ProofPower are not refutation oriented. The main target is a backchaining facility which searches for a proof of the conclusion of the current goal from premises and rules drawn from the assumptions and elsewhere.

### 2.13 Z in HOL - the story of ProofPower

An analysis of the ideas behind the engineering of a proof tool to support the Z specification language by semantic embedding into HOL. From the ideas of Leibniz via the creation of the new academic disciplines, first of Mathematical Logic and then of Computer Science, we trace the roots of one small step in the mechanisation of reason.

### 2.14 The Story of ProofPower

History and rationale of the development of ProofPower.

### 2.15 An Introduction to ProofPower

An introductory illustrated description of ProofPower (not progressed far enough to be useful).

### 2.16 X-Logic Models

Formal models of various aspects of X-Logic in Z

### 2.17 Category Theory

Formalisation of some of the concepts of category theory in ProofPower-HOL.

## 2.18 The Category of Categories

Explorations into the possibility of contructing non-well-founded foundations systems which are ontologically category theoretic and include a category of all categories.

## 2.19 NFU and NF in ProofPower-HOL

Three formalisations in ProofPower-HOL are undertaken of NFU and NF. One is based on Hailperin's axioms. Another tries to follow Quine's original formulation by expressing stratified comprehension as a single higher-order axiom (axiom schemes are not supported by ProofPower. The last is a finite axiomatisation based on one originating with Holmes.

## 2.20 PolySet Theory

This document is concerned with the specification of an interpretation of the first order language of set theory.

The purpose of this is to provide an ontological basis for foundation systems suitable for the formal derivation of mathematics. The ontology is to include the pure well-founded sets of rank up to some arbitrary large cardinal together with the graphs of the polymorphic functions definable in a polymorphic functional language such as ML, and the categories corresponding to abstract mathematical concepts.

The interpretation is constructed by defining "names" or "representatives" for the sets in the domain of discourse by transfinite inductive definition in the context of a suitably large collection of pure well-founded sets. A membership relation and a equality congruence are then defined simultaneously over this domain, so that the domain of the new intepretation is a collection of equivalence classes of these representatives. Relative to a natural semantic for the names, the definitions of these is not well-founded, and special measures are required to obtain a fixed point for the defining functional. These include choice of a suitable boolean algebra of truth values for the defined relations, and the location of a suitable subdomain of the representatives.

## 2.21 Set Theory as Consistent Infinitary Comprehension

This paper is concerned with set theory conceived as a maximal consistent theory of set comprehension. This is interpreted by looking for large subdomains of a notation for infinitary comprehension, and the theory is developed from such interpretations.

## 2.22 Surreal Geometric Analysis

This document is an exploration into formalisation of geometric algebra and analysis using surreal numbers instead of real numbers.

## 2.23 A Higher Order Theory of Well-Founded Sets

An axiomatic development in ProofPower-HOL of a higher order theory of well-founded sets. This is similar to a higher order ZFC strengthened by the assertion that every set is a member of some other set which is a (standard) model of ZFC.

### 2.24 Infinitarily Definable Non-Well-Founded Sets

This paper is my second approach to set theory conceived as a maximal consistent theory of set comprehension. The principle innovation in this version is to simplify the syntax by removing comprehension, so that the syntactic category of term is no longer required.

### 2.25 More Miscellanea (misc1, misc2)

This theory is for miscellanea which cannot be put in theory "rbjmisc" because of dependencies on other theories. It consists primarily of things required in the documents on non well-founded set theories, but not specific to that work, which make use of galactic set theory or fixed point theory. Since I moved my non-well-founded foundational work back from set theory to combinatory logic using version of well-founded set theory with urelements it has been necessary to replicate those definitions required which depend upon well-founded set theory in the context of this other version of well founded set theory. For that reason this document is in the process of being restructured as three theories, one of material which does not depend on the well founded set theory, and one for materials dependent respectively on each of the two versions of well-founded set theory. These are the theories misc1, misc2 and misc3.

### 2.26 Infinitarily Definable Sets

This is my third approach to set theory conceived as a maximal consistent theory of comprehension. It differs from the previous attempt (in t024) by simplification of the treatment of infinitary logic, allowing only a single binary relation.

### 2.27 Infinitary First Order Set Theory

The abstract syntax and semantics of an infinitary first order set theory.

### 2.28 Aristotle's Logic and Metaphysics

Formalisation in higher order logic of parts of Aristotle's logic and metaphysics.

### 2.29 Analyses of Analysis: Part II - Introduction

The introductory chapter to the second part of Analyses of Analysis.

### 2.30 Russell and Wittgenstein, Logic and Metaphysics

Formal models of aspects of the Tractatus Logico-Philosophicus and Russell's philosophy of Logical Atomism.

### 2.31 Pure Type Systems and HOL-Omega in ProofPower

The abstract syntax and semantics of Pure Type Systems and HOL-Omega in a formal higher-order theory of well-founded sets.

### 2.32 The Logic and Metaphysics of Leibniz

Formal models of aspects of the Logic and Metaphysics of Gottfried Wilhelm Leibniz.

### 2.33 The Proposition

A place to play formally with the concept of proposition. This actually started as a formal look at some of Harvey Friedman's ideas, particularly his concept calculus but also BRT theory, and I think somehow I got the idea that the relevance of this to me was something to do with propositions. Anyway, it hasn't really got anywhere.

### 2.34 Grice on Vacuous Names

Formal analysis (using Higher Order Logic with ProofPower) and commentary on Grice's system Q (G, $G_{HP}$) first presented in his paper *Vacuous Names*.

### 2.35 Higher Order Logic

At present this document is a (small) mess pot of explorations of how one might go about presentation of Church's Simple Theory of Types and ultimately ProofPower HOL using Standard ML and/or ProofPower HOL. I am interested both in exposing exactly what Church said, comparing the details of his system with those of ProofPower HOL and discussing the reasons for the differences, but also I am looking for an interesting and digestible way of presenting ProofPower HOL to philosophers or other groups without much IT background. Its doubtful that all these objectives are compatible, and so far my attempts have not been in the least impressive, but I probably will keep picking at it and may eventually come up with something useful.

### 2.36 Equivalences, Quotients, Universal Algebra and Lattice Theory

This is a limited development of universal algebra and lattice theory for the purposes of X-Logic.

### 2.37 Abstract Models for Concrete Constructions

Some preliminary explorative modelling of electronic circuits.

### 2.38 An Illative Lambda-Calculus

This is an approach to illative lambda-calculi via construction of an infinitary calculus in a well-founded set theory.

### 2.39 A Higher Order Theory of Well-Founded Sets (with Urelements)

This is a modification of the pure set theory GS to admit urelements.

### 2.40 More Miscellanea

This theory is for miscellanea which depend upon well-founded set theory with urelements (GSU). It also has misc1 as a parent.

### 2.41 Model Theory and Universal Algebra (II)

This is a second exploratory approach to Universal Algebra.

### 2.42 Meaning, Modality and Metaphysics

A partly formal discussion of modal concepts leading to a discussion of certain kinds of metaphysics.

### 2.43 Pluralities and Sets

This is a formal exploration with ProofPower of a topic addressed by Øystein Linnebo in a paper under the same title.

### 2.44 Formal Semantics and Deductive Methods

A discussion of formal semantics and semantic embedding.

### 2.45 Iterative Foundational Ontologies

A broad discussion of ontologies for mathematics and abstract semantics.

### 2.46 Axiomatic Method

A

### 2.47 Illative Combinatory Logic

Another approach to illative combinatory logic, based this time on the hol4 example on pure combinatory logic. Mainly an attempt to understand why that example is so much simpler than my own efforts.

### 2.48 Infinitary Induction in HOL

This paper explores some ideas for providing general support in HOL for structures defined by transfinite induction, by exploiting a strong infinity axiom expressed in terms of a well-ordering on a new type of "'a ordinals".

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