B L A C K W O O D   D E S I G N S

Informal Lectures on Formal Semantics

OVERVIEW

This is a review of the contents of *Informal Lectures on Formal Semantics* (1989) Emmon Bach. It covers Intensional Semantics, esp. Montague Semantics, and a sketches how to handle topics beyond those in Montague's original paper, and introductions such as *Introduction to Montague Semantics* (1980) by David Dowty, Robert Wall, and Stanley Peters.

What do you call a merry mereologist who has fallen to pieces?

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BOOK REVIEW

Informal Lectures on Formal Semantics

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This note is a review of the book *Informal Lectures on Formal Semantics*, to help understand the narrative.

Informal Lectures on Formal Semantics
Emmon Bach, 1989
State University of New York

The book admirably tries to avoid being too abstract, yet brief. However, it still uses many unclear terms and phrases. I attempt to clarify below these terms and meaning(s). I also shortened the narrative to be more coherent.

1 Model theoretic semantics

formal semantics – p7
model theory – p6

Formal semantics is an attempt to precisely or explicitly find the meaning of an expression. *Model theoretic semantics* is one *mechanism* to associate expression with this meaning. Model theories use mathematical tools to do their work. It does this by systematically "set[ing] up some kind of representation of the different meanings or structures."

metaphysics – p98

This representation and expression of meaning borrows logical theories of *metaphysics*, including:

- Epistemology or theory of knowledge to know whether an expression is true
- Logical modality
- Moral obligation or desirability
- Physical possibility

expression

An *expression* is a word, term, phrase, statement or other object in the source domain. This is derives from the philosophical view that semantics should be universal or, at least, "more universal" than other parts of language.

The rest of the section includes descriptions of:

- A sketch of the interpretation process
- What do you get from interpreting an expression

1.1 An introduction to role of truth

The lectures do not explicitly describe statements, assertions and the like. In model-theoretic semantics these statements are interpreted to their truth value – whether or not a given statement are true, false, indeterminate, or undecidable.

Theory of truth for a language. The model-theoretic approach is the *form* of how one goes from expressions of a language to some sort of authoritative sources (e.g. theories) to evaluate whether a statement is correct. Bach emphasizes no judgement is made on those sources. (Mathematicians are obsessed with form past the point of inapplicablity)

theory of truth – p24

1.2 An introduction to meaning

A *meaning* is a "mental object of some sort" "determined by thought", perhaps a "relation between" things usually "determined by the way the world is." Meaning, in model theoretic sense, has two broad parts:

meaning – p3,5,78

- A *denotation* is what a given expression designates: noun's have an extension, expressions have an intension, statements have a truth value. There is no distinction between denotation and extensions in this text. Denotation is also sometimes used to refer to the procedure for determining the designation of a given designation, often a function that is given an expression to evaluate. This is better understood as interpretation (see the next section).
- An *extension* is sets of things in a world, or other values.
- intension is a formula transformationor function on expression. This handles imaginary things under discussion, such as unicorns.

denotation – p5,44

extension – p72

intension – p72

Reference is a specific type of denotation, or a synonym; any distinction is not made clear.

reference – p40

What should one do if an expression does not refer to anything? For example "the King of France." Is the extension a null set, or is it inderminant? Similarly is the denotation "The King of France is bald" false, or indeterminant? Different logicians take different approaches.

indeterminant – p?

More generally, what if the quantity (count) expected doesn't match: what if there were three Kings? Both no Kings (0) and three (3) do not match the expected quantity of 1 for "the". Bach points this out, without offering a solution

The specific structure of a denotation is specific to the kind of theory, and will be discussed in later sections. The basics include:

- Identifying individuals
- Properties
- Indexicals

1.3 Interpretation structure

Interpretation with respect to a model theory is "some way of assigning denotations in a certain model structure to expressions in a language." This is done with several elements:

interpretation – p22

***Table 1:** Elements of interpretation structure*

what	*symbol*	*description*
model structure	M	"The kinds of things needed to interpret the languages" or the interpretation system.
evaluation function	D[1]	"a way of assigning elements in the model structure to the

[1] D is probably for denotation

		expressions of the language." That is, a procedure that maps an expression to the denotations, using the model.
variable value assignment[2]	g	A table of variables and their respective values.

A given interpretation structure does not necessarily have all of those items. Bach felt the first two were the most important.

A model structure based on logic and sets may include the following elements:

logic and set based model – p30

Table 2: *Elements of a model*

what	*symbol*	*description*
entities	E	The sets of individuals and things that can be interpreted by the model.
truth values		{0,1} and possibly indeterminant
terms		?
times	T	A set of times, with a certain ordering relation R on them
worlds	W	set of possible worlds

What are the structure of the elements in these models?

entity - p82

- Entity may be a kind, object, individual, stage, property, etc.
- Term: Not described.
- Time: a time could be anything you want: a dimensionless instant, a span, etc.
- World: The structure of a world varies, and will be discussed in various later sections. However, positions within a world are generally not handled.

1.4 A little notation

This is a brief note on how the expression to be interpreted is marked. The traditional method is to mark the beginning of an expression or phrase with ⟦ and the end with ⟧, and with superscript parameters to guide evaluation. This is interpreted as being fed into the evaluation procedure. If Bach uses any such marking, it is D(for the beginning, and) for the end.

1.5 Interpretation procedure

Approach (earlier), layered

1. Directly interpret the terms
    a. Look up in the table of constants, if not there,
    b. Look up in the assignment table, if not there, then
    c. Formulas and predicates that combine
2. Apply the rules in M to match the expression, and apply the semantic rules
3. May create expressions in terms of an another model & evaluations functions, and interpreted with that.

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[2] The text uses "assignment of values to variables" which implies that any given value can have at most one variable.

a. I've not seen any discussion whether the network of these models & evaluation functions (ie, M1&D1 refers to <M2,D2> etc) must be acyclic or not. Can parts of English be translated into French for better interpretation, while French may be translated back into English for better interpretation? If so, what does risks & limits does this pose?

What does the interpretation of an expression produce?

- Montague initially proposed:
  - Evaluation of a sentence produces a true or false value (as defined in the truth value set)
  - Evaluation of other expressions may produce a truth value, a set, or other value.
- Configurational theory of interpretation "different structures for different interpretations"

configurational theory of interpretations - p48

1.6 Possible worlds

Possible world theories involve multiple alternative possible circumstances, not just the one of the present world. Possible world theories are a sub-theory of model theory. They incorporate theories of *modal logic.*

possible world – p26
Saul Kripke, 1960s

Why support many worlds? Simple logics, such as predicate calculus, do not support adverbs (e.g. "slowly"), tense, or auxiliaries / moods (subjunctives). This motivates the use of multiple worlds, and possibly multiple models.

p16

This approach uses *accessibility relations* as the a basis for conditional statements, and concepts like possibility, neccessity, and so on. The relation is true for "worlds that are 'accessible' to the the one you start with."

accessibility relation – p31

tense - same world at different times. The approaches incorporate theories if *tense logic.*

tense - p29

The extension of an expression depends on the world and time to produces individuals, sets, or sets of pairs. There are many different opinions what a world is made of.

p29

Bach has the world including mapping term to individual it denotes. Most like this is to a pair <time, denotation> in a set. Given the *time*, one can then find the denotation.

p12

1.6.1 Particular situation

Cresswell proposed that a world is composed of basic particular situations. There are three close definitions of these situations:

Logic and Language, *Max Cresswell, 1973*

- These are "sets of (occupied) space-time points".
- Carlson calls these *stages* (of the individual), which are "time and space limited manifestations of an object or kind"
- Link see them as "the quantities of matter that correspond to individuals at particular times and worlds"

stages - p83, 96

A *manifestation* for an individual is a function f:world → subworld (The subworld is part of the given world)

manifestation – p104

1.6.2 Identification

individual constants -- denote particular individuals, aka names

The central issue is a given person the same in every possible world or not? This is two kinds of identifiers, called "designators":

A *rigid designator* refers to the same individual in every possible world. *rigid designator – p97* *Saul Kripke*

Alternatively, each world has its own individuals – a proper name refers to different individuals in different worlds. The different individuals have different designators. *Counterparts* of individuals in the worlds is used to allow discussion of the conventional Richard Nixon, the Richard Nixon that lost the 1968 election, and so on. *counterparts – p32*

individual: e.g. the current Miss America *p73*

Transworld identification *David Kaplan*

1.6.3 Properties of entities

Anything that can be identified has a *property set* for a world, time pair. Each element of that set is a property. A *property* is a set of entities that have that property. *property – p42-3* *Peter Geach, 1972*

- When an entity is capable of action involving no other entity. For instance "John walks" corresponds to John having a property that means "is a walker"
- When an entity is capable of an action or being in a state involving other, this involves several properties. "John loves Mary" has the property <*loves, Mary*> in John's property set, and <*loved-by, John*> in Mary's property set.

Properties are also considered entities (Chierchia) *p89*

1.6.4 Identical things and sameness

"Two things are identical [if and only if] all their properties are the same" – but is that restricted to just a time and world, or across all times and worlds? *p42*

1.7 Kinds

Some entities are a *kind*, not an existing particular. For example, horse may be a kind, and Wilbur is-a horse. *kinds – p81* *Greg Carlson*

1.8 Events

Events and eventualities as a type of entity. *events - p113* *Donald Davidson*

There are two kinds of *realization*. One maps kinds to instances. The other maps an instance or kind to stages. *realization – p94* *Greg Carlson*

1.9 Intension vs Extension

When interpreting an expression as an *extension*, specific, existing members of the world are considered. *extension – p49*

When interpreting an expression as an *intension*, formulae are produced. *intension*

Meaning postulates "a way of putting some explicit [extra] constraint on the models or worlds which we want to admit as possible interpretations of some languages." These steer the interpretation away from certain extensional interpretations. *meaning postulates – p97*

1.10 Summary of concepts

Table 3: *Accessibility relations for propositions*

what	*authority*	*description*
'believes'	Montague	f:individual $\times$ proposition $\rightarrow$ t/f

		relation between individual and proposition
individual	Montague	e st e∈E
	Cresswell	f:world → subworld (of the given world)
individual concept	Montague	f:world×time → individual
	Cresswell	f:world → individual
manifestation	Cresswell	f:world → subworld (of the given world)
name		{property set | name ∈ property set} the set of sets which the name is part of
property	Montague	f:world×time → sets
proposition	Montague	f:world×time → t/f
situation type		f:relation[3]×individual → t/f

1.11 Other model theoretic theories

There are other kinds model-theoretic semantics.

Structural semantics. Not possible world semantics, nor truth based. *Barwise & Perry*

2 Logic and set based models

The semantics are based on creating formal systems, although Bach does not define what this is. A *formal system* is comprised of: *formal system - p7*

- Alphabet: A fiinite set if symbols (or terms) to be used within the formulae
- A grammar that describes how wff are constructed
- A set of axioms
- A set of inference rules

Model based approaches prefer to be constructed *compositionally*. That is, the meaning of complex expression is based on the meaning of the constituent parts and how they are combined. Models are also often built by combining simpler models. *compositionality – p35,46*

The semantics start with a formal system based on boolean algebra (*propositional calculus)* and construct other formal systems that incorporate it. This is done using *first order languages*, which have quantifiers. Later stages may use *higher order languages*, or sets. *propositional calculus – p70*

No comment is made that the sets of entities must be the same in the models. It seems plausible some models may have different sets of entities.

constants

Variables denotes individuals using value assignment, like pronouns *variable - p6*

2.1 Sets

This approach assumes simple set operations (membership, subset, union, complement, and power sets) and a small number of specials sets:

Table 4: *Special sets*

what	*description*
Ø	empty set
U	The universal set (everything is in this)

[3] relation can be n-place

Mentions use of families of sets, when free of the paradoxes that sets of sets can have.

2.2 Formula

A *formula* is a logic expression, interpreted in terms of well understood restricted language — *formula*

A *well-formed formula* is a formula constructed according the rules, and therefore can be given meaning in the system. — *well-formed formula*

An *open formula* includes variable not under the scope of a logical operator (all, exists). Most often these are functions. — *open formula*

Two formula that are *logically equivalent* are true in the same models and false in the same models. — *logically equivalent -*

2.3 Functions and predicates

Functions have a signature, composed of the domain and codomain. A functions arguments are open variables, whose values must be in the *domain*. The value result interpretation of the function (once all the variables are bound) is in the *codomain*. — *domain, codomain*

A *single argument function* is a relation between two sets. It maps from a domain (a set) to codomain (a set). — *single argument*

A *binary functions* is often described with a set of ordered pairs. — *binary function*

A *total function* is "a function where you always get a value for every element in the set on which it is defined." — *total function – p123*

Partial functions are "functions from some domain that yield values only for a subset of the objects in the domain" — *partial function – p123*

A *characteristic function* of a set simply checks to see if the argument is a member of the set, returning true or false. — *characteristic function*

The approach breaks down functions into one place function, to allow stepwise composition (driven by the stepwise decomposition of the expression). Most often the single argument functions seem to take a set of sets producing a set of sets.

A *predicate* is a just a "functionf from objects of some kind to [a] truth value." However, Bach also says: — *predicate – p59*

- one place predicate denote sets
- two place precidates denotes sets of ordered pairs of individuals

Complex expressions (formula) can be formed by combining predicates, and terms.

2.4 Quantifiers

A quantifier is "a thing that goes together with a variable to find [possible values of] free variables." This act as "functions from sets to truth values." — *quantifier – p14-5, 59*

A *universal quantifiers* is an operation such as every, some, atleast one. They do not do well with comparison, such as most, or many vs some. — *universal quantifier – p14-5*

A *generalized quantifier* is "a set of sets (included in the domain of E)." The quantifier and expressions perform set operations. — *generalized quantifier – p56*

3 Application of model-theory to natural language

Montague applied model-theory to natural language, treating its interpretation as a formal system. How well suited is this for natural language.

"What kinds of model structures are most appropriate and relevant for studying the semantics of natural languages?" *p16*

"What sorts of model structures do we want to set up if we want to try to pursue the semantics of natural languages in a model-theoretic manner?"

The model M for interpreting natural language has the following elements:

- A *grammar*, describing *syntax rules* and *semantics rules.*
- A *lexicon* that maps a term to it's definition
- A set of *categories*, which are the possible parts of speech
- *Syncategormatic elements* (p37)

3.1 Grammar

The *syntax* is described using a *generative grammar*, which "an explicit statement of what the classes of linguistic expressions in a language are and what kind of structures they have." This allows "you to construct various kinds of expressions in the language by completely mechanical means." Syntactic Structures, *Noam Chomsky, 1957*

How to link the syntax to it's semantic interpretation?

- *Configurational theory of interpretation*. Chomsky's *government and binding* approach produces structures during the syntactic analysis. One would apply an interpretation to these structures. (Chomsky doesn't worry about the interpretation.) *configurational theory of interpretation – p48*
- *Derivational theory of interpretation*. Montague has a semantic rule for each syntax rule, without producing an intermediate structure. *derivational theory of interpretation – p48*

Categorial theories of grammar link semantics with syntax. Not used in linguistics much. *categorial theory - p126*

3.2 Parts

Montague added a type system, in part to avoid paradoxes:

- Each entity is associated with a type *p71*
- Terms have a type.
- The syntax interpretations are also associated with types.
- The syntax and semantics rules may refer to these types when determining the denotations to be applied. *p42*

It is difficult to model the semantics of many sentences in natural language, leading to a complex type system.

3.2.1 Nouns

A *noun phrase* denotes sets of properties. A given noun X is interpreted as a set of properties which X has. (Recall that each property is a set to which X belongs.) *noun phrase - p43*

Common noun phrases – CN(p) – are "expressions that give a natural basis for picking out those subsets of the domain we want to quantify over in [the] sentence" *common noun phrase – p55*

3.2.1.1 Plurals

Montague only dealt with singular. Others have worked on techniques to handle plurals. *plurals – p78*

- Michael Bennett: ⟦horses⟧ is the set of sets of horses. Presumably the set of power set of horse; that is, every possibly combination horses is a set (in the outer set). If given a list of individuals, that would form a set (in the outer set).
- Link used structures to handle the different combinations, including explicit lists of individuals.

Greg Carlson's *generic plurals* use kinds to handle abstract classes, such as "horse." *generic plurals – p81*

3.2.2 indefinite description

An *indefinite description* ⟦a *noun-phrase*⟧ is interpreted as the set of properties P s.t exists y is in the sets of properties denoted by the noun phrase, and y has property P. That is:

⟦a *noun-phrase*⟧ = {P | y∈⟦*noun-phrase*⟧ ⋀ P∈y}

3.2.3 Determiners

A *determiners* are "an expression that denotes a function from sets to quantifiers (sets of sets)"; that is, they become logical expressions employing quantifiers. This includes *every, some, many, most*. *determiner – p57*

The interpretation of ⟦every child⟧ is sketched as the intersection of the properties of each child. *every - p43*

Bach divides determiners by their relationship with the model:

- *strong determiner* – truth value does not depend on the model (that is, it is the same truth value for all models) *strong determiner – p59*
- *weak determiner* – truth value depends on the model *weak determiner – p59*

3.2.4 Verbs

A *verb* phrase accesses properties of the nouns (object or subject). For the sentence "John talks" property of talking is in the set of properties that John has (and John is in the set of talkers). For "John loves Mary", John's property set contains the property "loves Mary", and Mary's property set contains the property "loved by John." *verb – p47*

It is trick to work with *verbal aspect*, such as in the progressive form, *stative* and *nonstative* verb which describe a state of being and an action (respectively). *verbal aspect – p91*

3.2.5 Indexicals

Indexical are context dependent items, like pronouns (I, you, it, etc). *indexicals – p105*

3.2.6 Summary

Table 5: *Summary of parts of speech and logic form*

what	*authority*	*description*
adverb	Montague	f:proposition → t/f
determiner		quantifier on a set
indeterminate phrase	Montague	predicate
indexical		
noun (singular)		
noun (plural)		{s | s is an n}
noun phrase		general quantifier
property of a noun		the sets mentioned earlier for noun

verb	Montague	relation

3.3 Ambiguity and vagueness

In practice, more than one interpretation "can be assigned to an expression." *ambiguity – p43*

Donkey sentences are a famous class of *structural ambiguity*. "Every farmer beats a donkey" may refer to one donkey, or many. But when "Mary hugged and kissed a bystander" did she hug one person then kiss another?s *structural – p35,122*

There are theories of vagueness "precise ways of building vagueness into a theory of meaning." These accommodate fuzzy terms, grading adjectives and adverbs, and so forth. *vagueness – p122*

3.4 Dialog or conversation

context of use – using a fixed structure, explicitly tracking the list of speaker, listener, etc. doesn't seem to work. Context is a situation, but nor further detail is given. Cresswell had another theory, but it is not described

3.4.1 File change semantics

Irene Heims' file change semantics and Hans Kamp discourse representation theory. "interposes a theory of discourses between the expressions of language and the model or world which ultimately determines the truth of the expressions" *file - p116*

A *discourse* "creates a file of information.. [first] draw[ing] upon a common basis that the speakers share… [then] created as the conversation proceeds." *discourse – p117*

An *assertions* "introduces a certain entity into the discourse and gives.. pieces of information about it." *assertions – p117*

"Indefinite and definite descriptions are understood not in quantification terms but in terms of directives for updating a file". If an *assertion* refers to an item not already in the file, it is *accommodated* by adding it to the file. *accommodation process – p117*