Guidelines

for Formal Specification and Verification

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Outline

FOUNDATIONS

SEMANTICS COMES FIRST!

Famous slogan of Joseph Goguen, must be understood through reason.

Current trend to neglect semantics, mostly because of intelectual incapacity.

Absence of formal semantics

=> things interpreted arbitrarily and not uniformly

=> *in-formal* method

=> non-sense concept of correctness.

Mathematical foundations

- There is a formal logical system, including both model theory (for semantics) and proof theory. Very desirable that these constitute an *institution*.
- The institution has additional structure and enjoys the properties supporting specification in-the-small and in-the-large.
- The eventual operational level of the proof theory (e.g. rewriting) is rigorously supported by mathematics.

Formal specification

- There is a formal specification language such that the language constructs correspond exactly to mathematical entities in the underlying logic.
- A specification consists of
  - a set of *axioms* in the underlying logic (this includes the specification of a corresponding signature), and
  - eventually, structuring constructs.
- Each such specification defines the *class of models* satisfying its axioms.
  - In the structured case, this is also determined by the structuring constructs (requires a bit of mathematical sophistication).

The whole point of formal specification:

axiomatic definition of certain classes of models.

Formal verification via Proof score programming

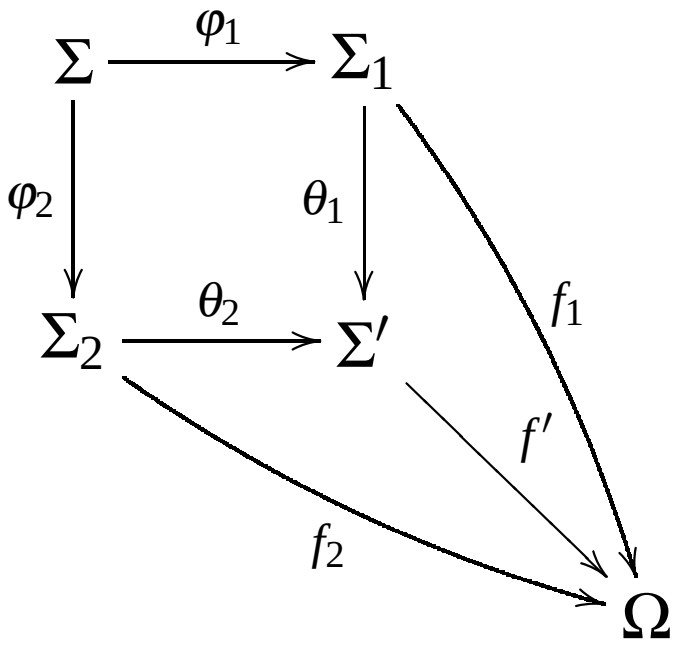
- Specification of the proof structure, including lemmas, conditions, proof tasks to be executed by the system, etc.
- Should be rigorously, directly and *transparently* based upon mathematical results lying foundations to corresponding proof methodologies.
  - In particular, this means to avoid abuse or even any use of extra-logical features of the language (such as ==, etc.)

Institutional structure and properties

Necessary for proper functioning of the specification language:

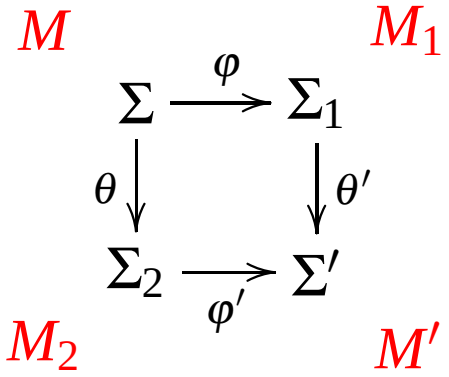
- Signature pushouts (co-limits)
- Model amalgamation
- Inclusion systems for signatures
- Free models (for initial semantics)
- Interpolation

Signature pushouts



Model amalgamation

$\mathscr{I}$ has model amalgamation when for each pushout of signature morphisms



for any Σ_i models M_i such that $\text{MOD}(\varphi)(M_1) = \text{MOD}(\theta)(M_2)$

there exists an unique Σ'-model M' such that

$\text{MOD}(\theta')(M') = M_1$ and $\text{MOD}(\varphi')(M') = M_2$.

Other useful forms of model amalgamation

Each of the following has its own applications.

- *Weak amalgmation*: requires only the existence of amalgamation M', not uniqueness. Quite often this is sufficient (such as for establising the Satisfaction Condition for quantifiers).
- *Semi-exactness*: amalgamation of model homomorphisms too.
- *J-amalgamation*: amalgamation from J-co-limits rather than just pushuts.

Inclusion systems

- Capture abstractly the concept of set-theoretic inclusion $A \subseteq B$.
- They constitute an alternative for the famous categorical concept of *factorization systems*.
- Signature inclusions, very necessary for the semantics of structured specifications.
- But also good applications to (categorical, institution-independent) model theory.

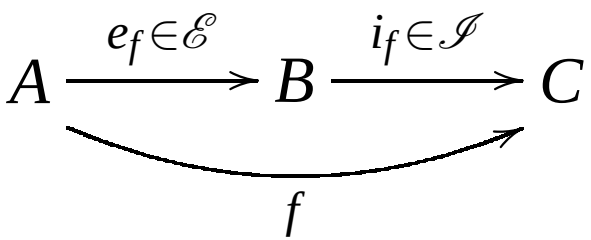
Inclusion systems: definition

$(\mathscr{I}, \mathscr{E})$ is a *inclusion system* for a category $\mathbb{C}$ if

- $\mathscr{I}$ (*abstract inclusions*) and
- $\mathscr{E}$ (*abstract surjections*)

are two sub-categories such that

1. $|\mathscr{I}| = |\mathscr{E}| = |\mathbb{C}|$
2. $\mathscr{I}$ is a partial order ($\subseteq$), and
3. every arrow f in $\mathbb{C}$ can be factored uniquely as

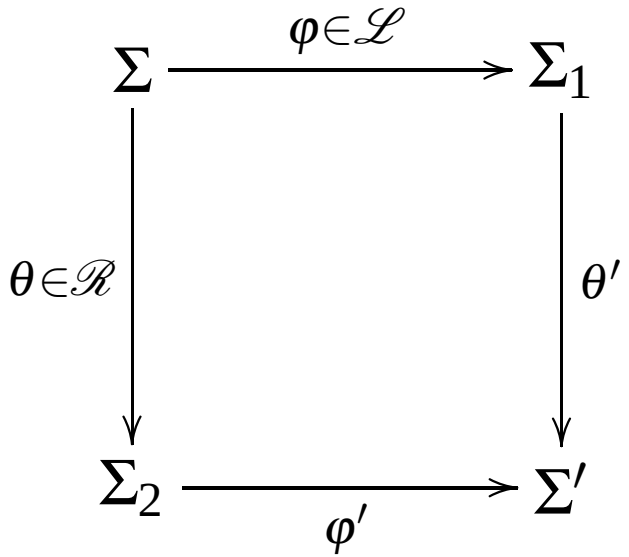


Properties of inclusiom systems

- It has $\cup$ and $\cap$.
- It is epic.
- It admits free idempotent extensions along signature inclusions.

$(\mathscr{L},\mathscr{R})$-Interpolation

For signature pushout:



for $E_i \subseteq Sen(\Sigma_i)$ if $\theta'(E_1) \models_{\Sigma'} \varphi'(E_2)$
then there exists $E \subseteq Sen(\Sigma)$ such that

- $E_1 \models_{\Sigma_1} \varphi(E)$ and
- $\theta(E) \models_{\Sigma_2} E_2$.

METHODOLOGIES

Methodologies

Vast topic.

Language without companion methodologies is un-usable.

One language - several methodologies.

Can methodologies support the usage of formal specification language without proper understanding of formal semantics?

ETHICS

Rapid deterioration of the academic environments

- Based upon competition for power and status.
- De-humanized.
- Critical moment to stop and reverse the trend, later may be too late.

What is wrong with (academic) Power/Status?

They are both evil since:

- ruthless competition to achieve them
- and even more to maintain them.

What is wrong with Competition?

(Academic) competition leads to fraud and exploitation.

- Authors by status often without understanding their authored papers.
- Students/junior researchers as means to achieve funding and research agendas.
- Conferences as platforms of self promotion, interest in other people work only for developing criticism.
- Plagiarism.

What is wrong with Intelectual Property?

- Heavily unrealistic, everything in the intelectual realm inter-dependent with a myriad of other things.
- Self grasping of ideas; similar to how animals mark their teritory.
- Plagiarism as an extreme form of intelectual property grasping; similar to how animals mark *others* teritory.

Solutions

- Refrain as much as possible from co-authorship with own students or junior researchers authors, or at least
- treat them as equal work partners if not as more important then ourselves.
- Regular single authorship, take responsibility to fulfill own research agendas by ourselves (like all great scientists have done in the past, e.g. Newton, Gauss, Einstein, Gödel, Turing, Kripke, etc.)
- Serve the development of our juniors free of own (research or competition) agendas; similar to good parenthood.
- Read more write less.
- Slow down.
- Do all these as a *satyagraha*.