# Change Management in Declarative Languages

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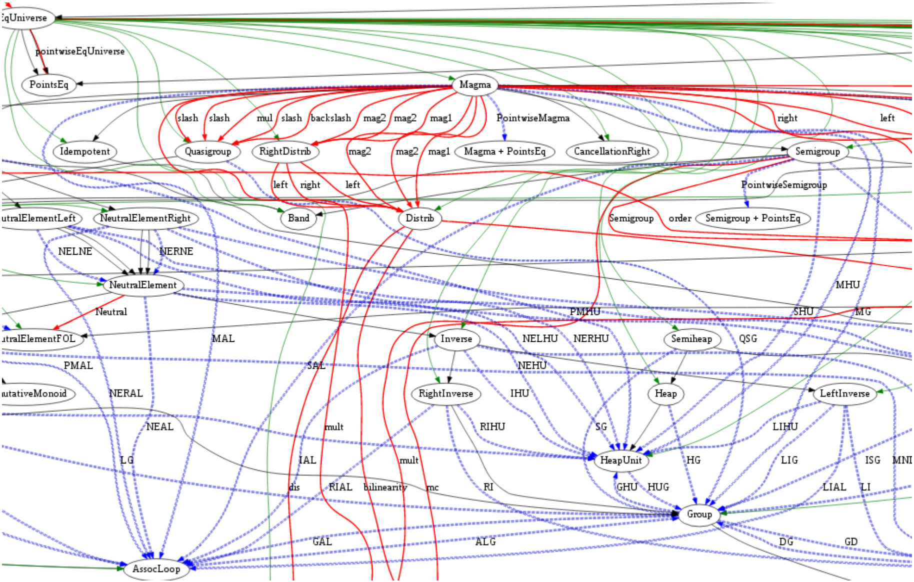
# Motivation

- mathematical knowledge grows relentlessly
- mathematics is intrinsically inter-connected
- formal mathematical libraries already too large to oversee
- need for adequate change management solutions

# Motivation: LATIN Library

- LATIN : an atlas of logic formalizations
  - inter-connected network of ∼1000 modules
  - based on the MMT/LF logical framework
  - highly modular (Little Theories approach)
- difficult to keep an overview (modularity helps but is not enough)
  - which declarations does the symbol $s$ depend on
  - which declarations depend on the symbol $s$


EqUniverse
pointwiseEqUniverse
PointsEq
Magma
slash
slash
mul
slash
backslash
mag2
mag2
mag1
PointwiseMagma
right
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Idempotent
Quasigroup
RightDistrib
mag2
mag2
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Magma + PointsEq
CancellationRight
Semigroup
left
right
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PointwiseSemigroup
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Band
Distrib
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order
Semigroup + PointsEq
NELNE
NERNE
NeutralElement
MHU
Neutral
PMHU
SHU
MG
NeutralElementFOL
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Inverse
NELHU
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Semiheap
QSG
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AssocLoop

# MMT

- a Module System for Mathematical Theories
- generic declarative language

  theories, morphisms, declarations, expressions

  module system
- OMDoc/OpenMath-based XML syntax with Scala-based API
- foundationally independent
  - no commitment to a particular logic or logical framework

    both represented as MMT theories
  - concise and natural representation of a variety of systems

    e.g. Twelf, Mizar, TPTP, OWL

# MMT-based MKM services

Foundation independence → MMT services carry over to languages represented in MMT

- presentation — MKM 2008
- interactive browsing — MKM 2009
- database — MKM 2010
- archival, project management — MKM 2011
- querying — Tuesday, MKM 2012
- editing (work in progress) — Wednesday, UITP 2012

- management of change (MoC) — now, AISC 2012

# Outline

## Management of Change

- MoC is not a new topic; usually involves
  - detect changes

    see if/how something changed
  - compute affected items

    maintain some notion of dependency
  - handle/identify conflicts

    in SE typically re-compile e.g. Eclipse

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## Outline

- semantic differencing
- fine-grained dependencies
- impact propagation
- some form of a validity guarantee

# MMT Example

## MMT Notions

| | |
|---|---|
| theories | contain constant declarations |
| constants | have components (type and definiens) |
| components | represented as MMT/OPENMATH terms |
| URIs | for each theory/constant/component |

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# Semantic Differencing

- we extend MMT with a language of changes
  - add ($\mathcal{A}$) and delete ($\mathcal{D}$) constants
  - update ($\mathcal{U}$) components
  - rename ($\mathcal{R}$) constants

| | | | |
|---|---|---|---|
| Diff | $\Delta$ | $::=$ | $\cdot \mid \Delta, \delta$ |
| Change | $\delta$ | $::=$ | $\mathcal{A}(T, c : \omega = \omega') \mid \mathcal{D}(T, c : \omega = \omega') \mid$ |
| | | | $\mathcal{U}(T, c, o, \omega, \omega') \mid \mathcal{R}(T, c, c')$ |
| Component | $o$ | $::=$ | $\mathtt{tp} \mid \mathtt{def}$ |

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- change detection ($\mathcal{G}' - \mathcal{G}$)

  identify differences between two theory graphs

- change application ($\mathcal{G} \ll \Delta$)

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- normal diffs

  <u>minimal</u> representatives w.r.t. $\equiv_{\mathcal{G}}$

- inversability of diffs

  $\mathcal{G} \ll \Delta \ll \Delta^{-1} = \mathcal{G}$

# Semantic Differencing: Implementation

## Change Detection ($\mathcal{G}' - \mathcal{G}$)

- view theory graphs as (nested) URI-indexed tables of declarations.
- new URIs $\rightarrow$ adds, old URIs $\rightarrow$ deletes, preserved URIs $\rightarrow$ (if changed) updates.
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## Change Application ($\mathcal{G} \ll \Delta$)

- follow the intuitive semantics of each change
- apply (in order) the changes from $\Delta$ to $\mathcal{G}$ (if $\mathcal{G}$-applicable)

# Fine-grained dependencies

- in MMT, validation units are individual components (types and definiens)
- we distinguish two types of dependencies
  - syntactic dependencies
    - declaration level
    - foundation-independent
    - occurs-in relation
  - semantic dependencies
    - component level
    - foundation-dependent
    - trace lookups during foundational validation

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    - component level
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    - trace lookups during foundational validation
- dependencies are indexed by MMT and are available at any time

# Example Revisited - Again

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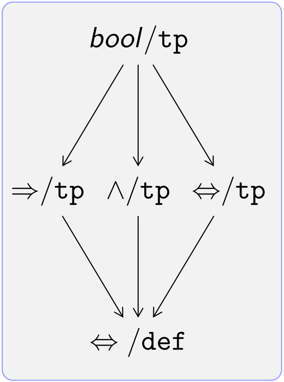

# Impact Propagation

- key idea : propagation as diff enrichment process
- impact propagation of a diff $\Delta$ is another diff $\overline{\Delta}$ that :
  - marks impacted components

    by surrounding with OpenMath error terms
  - automatically propagates renames

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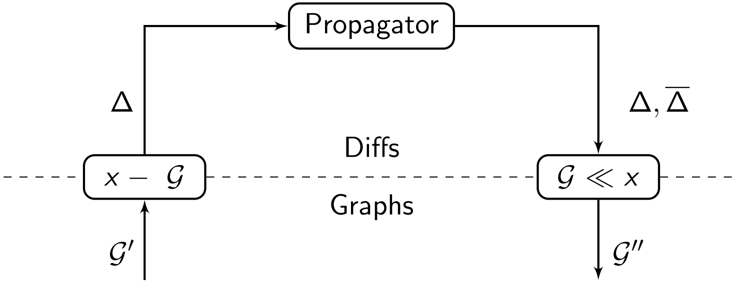
**Theorem**

*After all error terms are replaced with valid terms in $\mathcal{G} \ll \Delta \ll \overline{\Delta}$, the resulting theory graph is valid.*

# Workflow Example (relative to a graph $\mathcal{G}$)



# Example Revisited - Yet Again

$$\overline{\Delta} = \mathcal{U}(PL, \Leftrightarrow, \mathtt{def}, \lambda x.\lambda y.(x \Rightarrow y) \wedge (y \Rightarrow x), \boxed{\lambda x.\lambda y.(x \Rightarrow y) \wedge (y \Rightarrow x)}),$$
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# Evaluation : LATIN

| Dependencies | Components (%) |
|---|---|
| 0 – 5 | 1373 (79) |
| 6 – 10 | 271 (15.6) |
| 11 – 15 | 81 (4.7) |
| 16 – 26 | 13 (0.7) |

| Impacts | Components (%) |
|---|---|
| 0 – 5 | 1504 (86.5) |
| 6 – 10 | 101 (5.8) |
| 11 – 25 | 76 (4.4) |
| 26 – 50 | 31 (1.8) |
| 50 – 449 | 26 (1.5) |

- generally low number of impacts

  due to modularity

- however, high variance of impacts

  creates need for detection tools

- on average, types have 3 times more impacts than definiens

  validates our fine-grained approach

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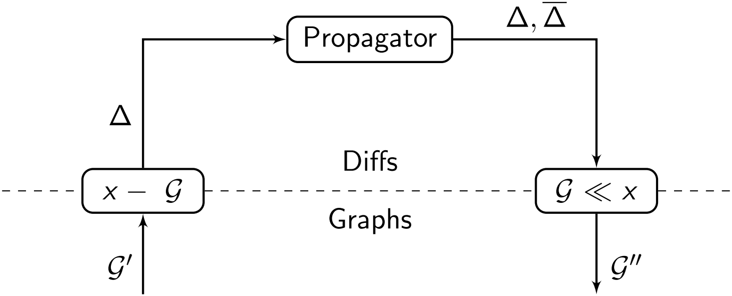
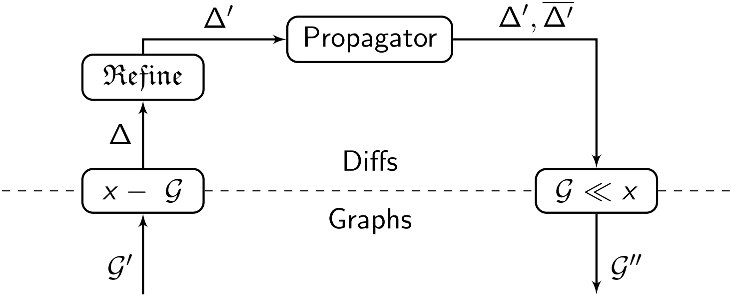
# Workflow Example (relative to a graph $\mathcal{G}$) – Again



# Workflow Example (relative to a graph $\mathcal{G}$) – Better



# Conclusion and Future Work

- MMT MoC : a change management solution for MMT
  - formal definition, theorems
  - supports transactions and roll-backs
  - uses fine-grained semantic dependencies
  - implemented in the MMT API
- future work (currently in progress)
  - refinement (add flexibility to the change language)

    towards an MMT theory of refactoring
  - integration with user interfaces