From Stack Traces to Lazy Rewriting Sequences

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Debugging lazy programs is hard.

Freja (Nilsson and Fritzson 1992)

Hat (Sparud and Runciman, 1997)

Buddha (Pope, 1998)

HOOD (Gill, 2000)

New Hat (Wallace et al., 2001)

HsDebug (Ennals and Peyton Jones, 2003)

Rectus (Murk and Kolmoldin, 2006)

GHCi debugger (Marlow et al., 2007)

StackTrace (Allwood et al., 2009)

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What do you think is Haskell's most glaring weakness / blind spot / problem? [Tibell, Knowlson 2011]

Inadequate Tools (50%)

[State of Haskell Survey 2011]

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Better lazy **step-based** tools are needed.

What's a "step"?

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- Evaluate expressions optimistically.
- To preserve lazy behavior, handle special cases:
  - non-termination
  - errors
- Too difficult to implement.

Idea #1:

Debugger shouldn't change the program evaluation model.

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- Step semantics correspond to low-level implementation
  -- unfamiliar to programmers.

Idea #2:

Debugger should use a high-level semantics familiar to programmers.

A reduction semantics-based tool

[Gibbons and Wansbrough 1996, Ariola et al. 1995]

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Idea #3:

A more "intuitive" lazy semantics is needed.

Our Work

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A step-based lazy debugging tool,

based on a high-level "intuitive" lazy semantics.

Our Work

- An algebraic stepper tool for Lazy Racket.

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- A new, "intuitive" semantics for lazy languages, $\lambda_{need\|}$
- Theory:
  - $\lambda_{need\|}$ corresponds to existing lazy semantics.
  - Tool is correct with respect to $\lambda_{need\|}$

$\lambda_{need\|}$

"intuitive"

$\lambda_{need\|}$

"intuitive"

=

syntactic

$\lambda_{need\|}$

"intuitive"

=

syntactic

+

substitution-based

Demo!

Semantics

$\lambda_{need\|}$: Syntax

$$e = \lambda x.e \mid e\ e \mid \ldots \mid e^{\ell}$$

$$E = [\,] \mid E\ e \mid \ldots \mid E^{\ell}$$

$$\ell \in \text{labels}$$

$\lambda_{need\|}$: Two-phase Steps

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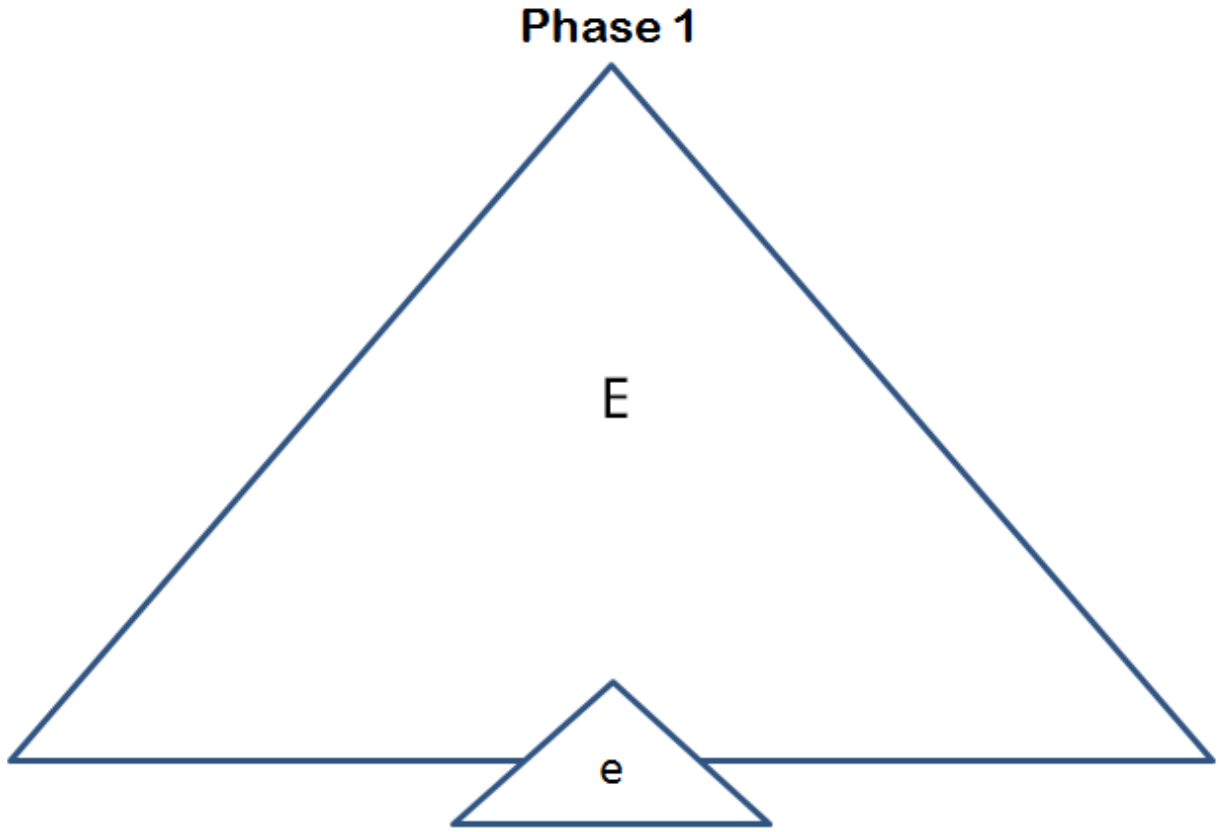
2) If redex is under a label, update all other identically labeled expressions to match.

$\lambda_{need\|}$: Two-phase Steps, Pictorially



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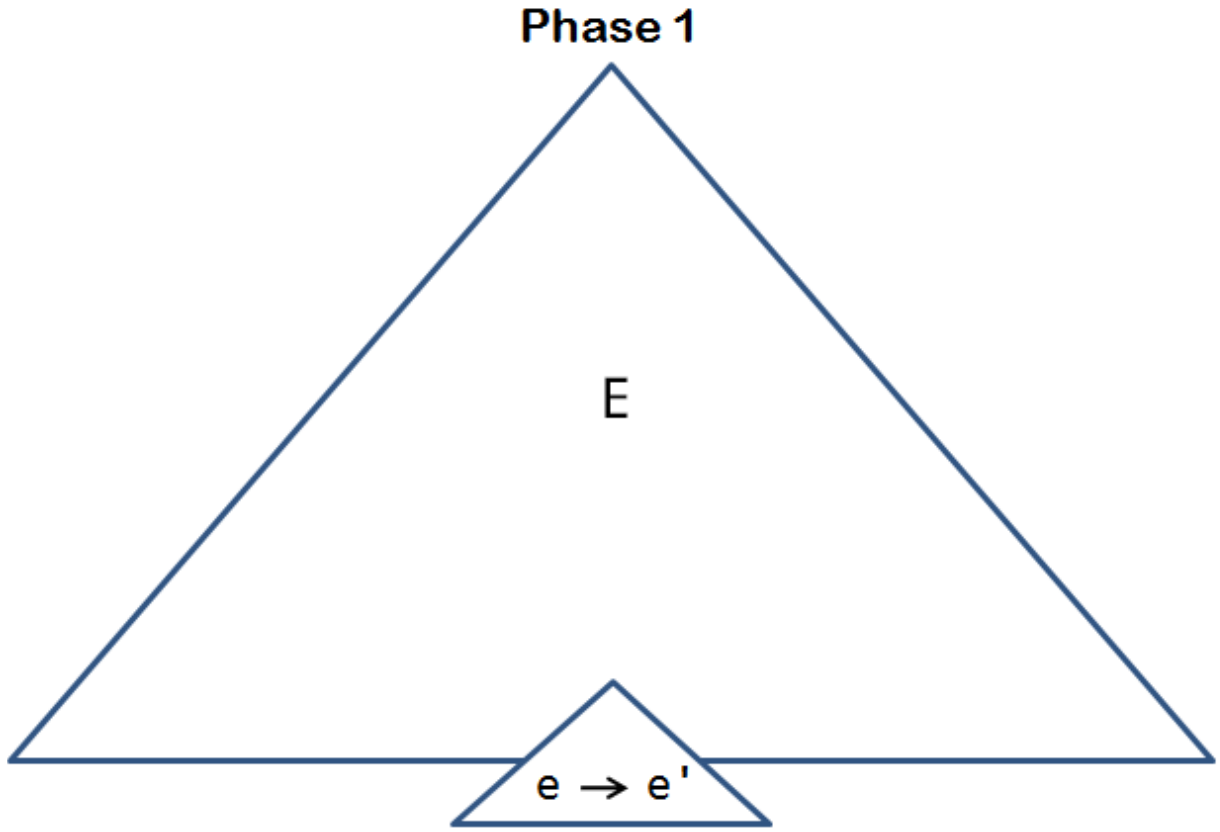

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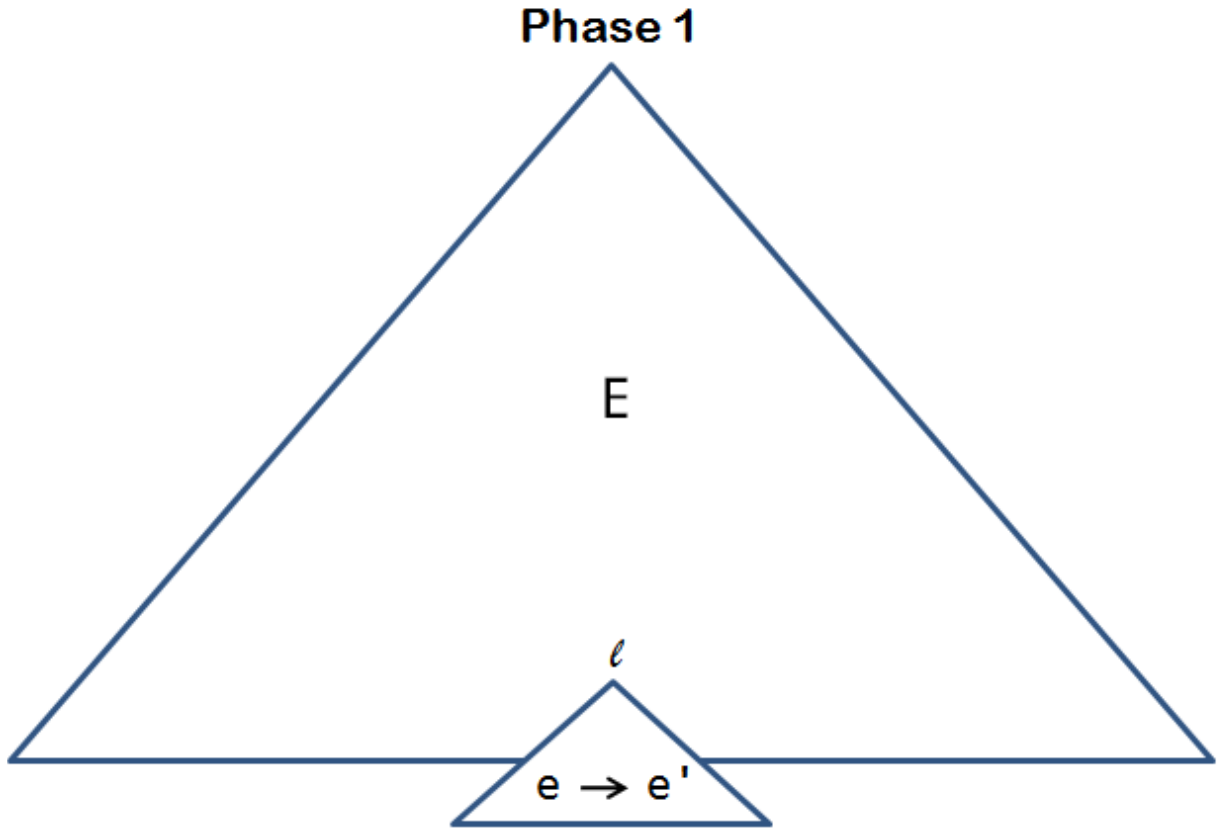

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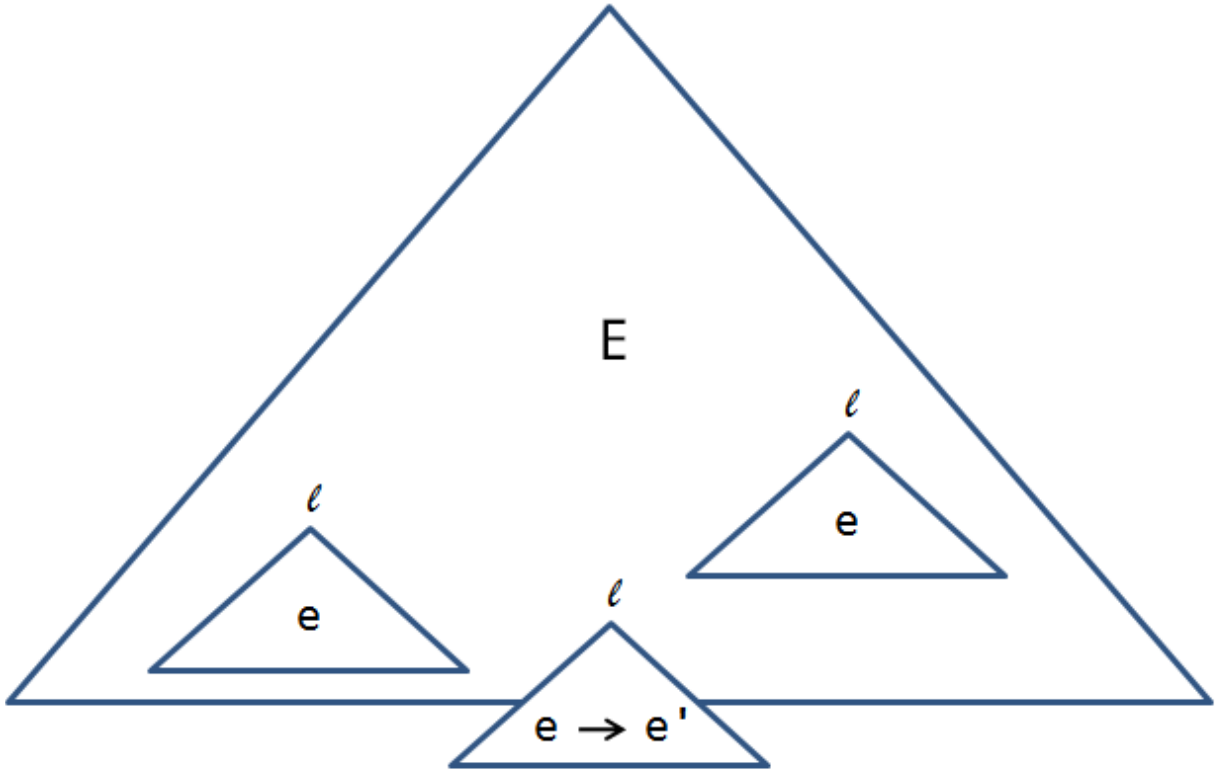
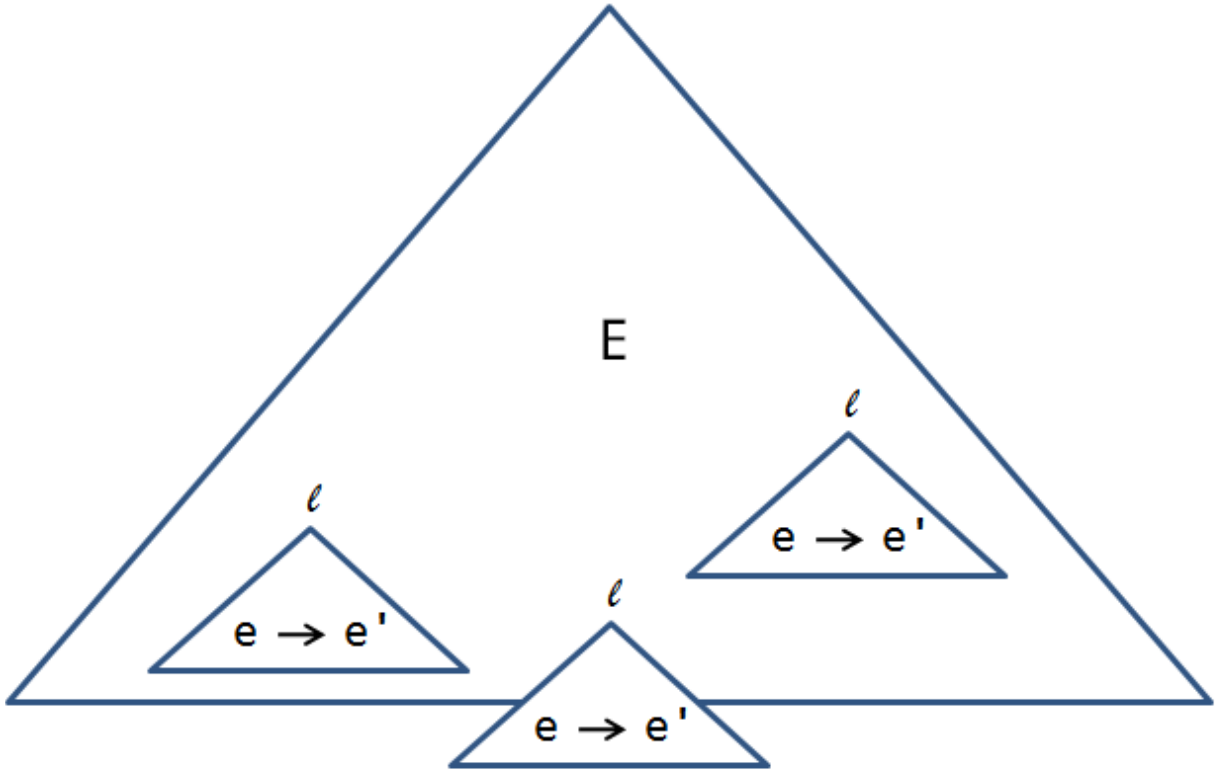


Phase 2

$\lambda_{need\|}$: Two-phase Steps, Pictorially

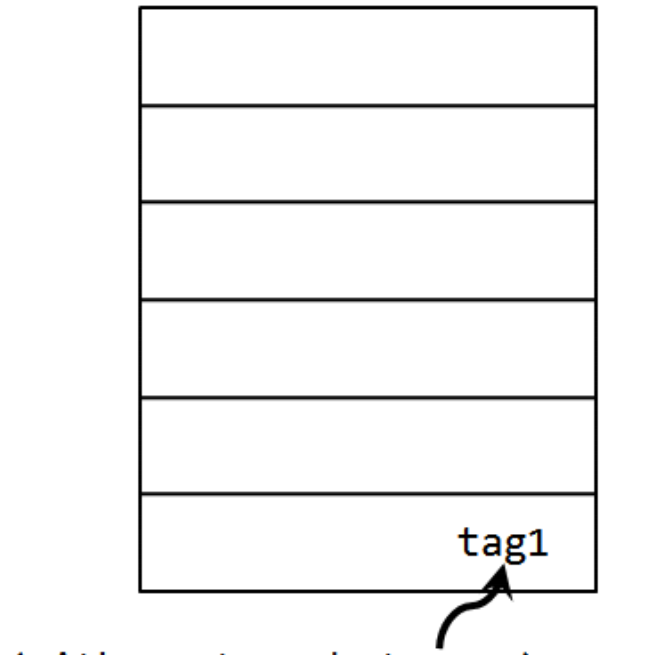


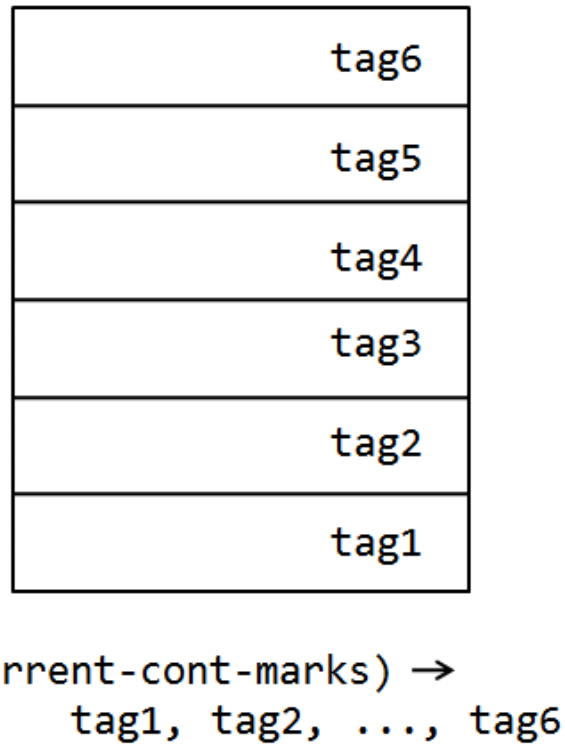
Phase 2

Implementation

Continuation Marks

Mechanism for lightweight stack access. [Clements 2001]





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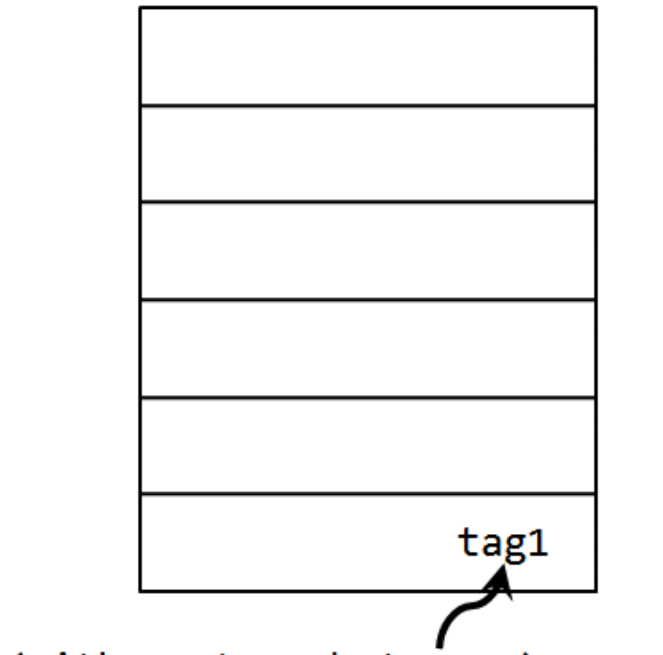

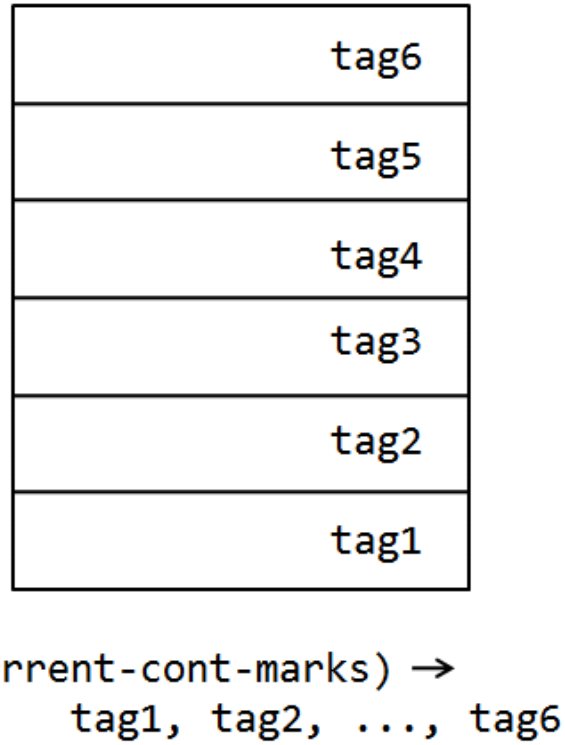

Continuation marks used in Racket implementation of:

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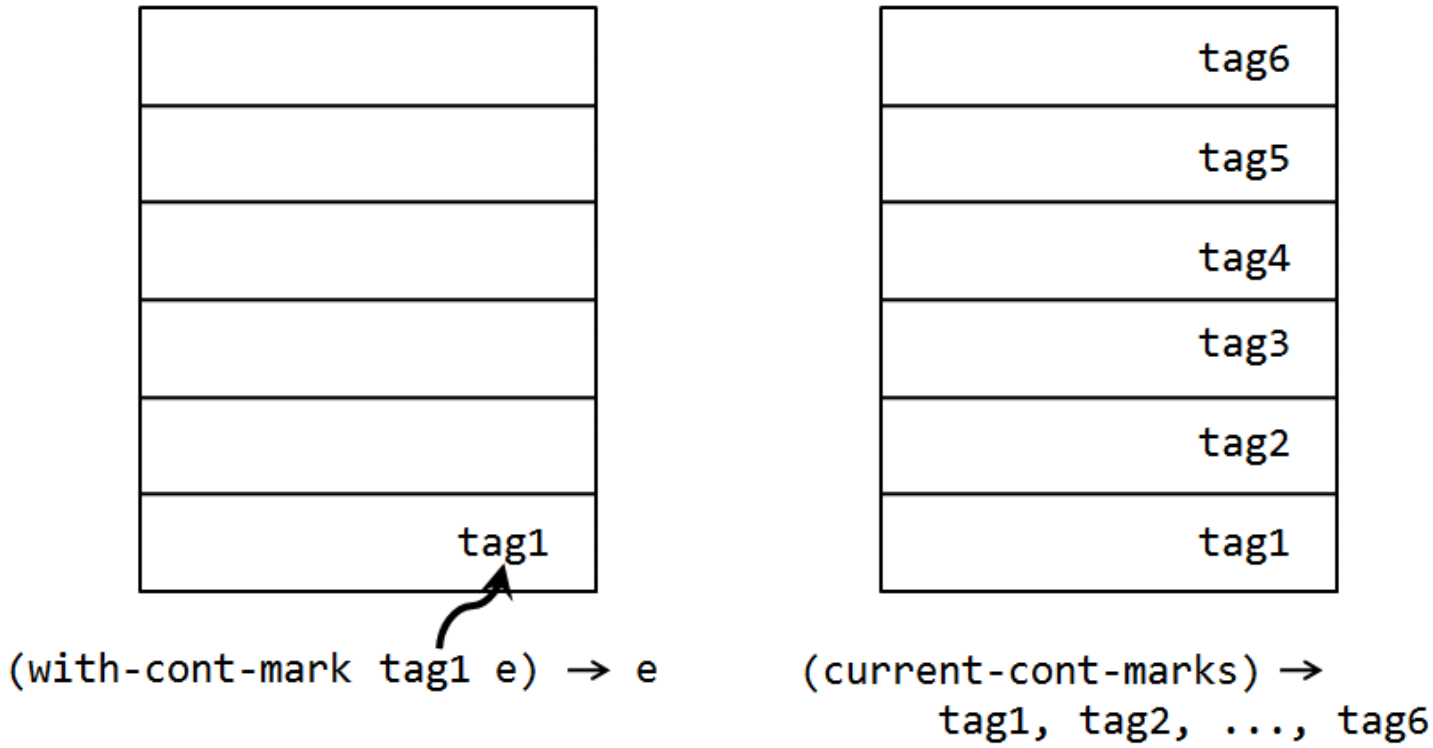
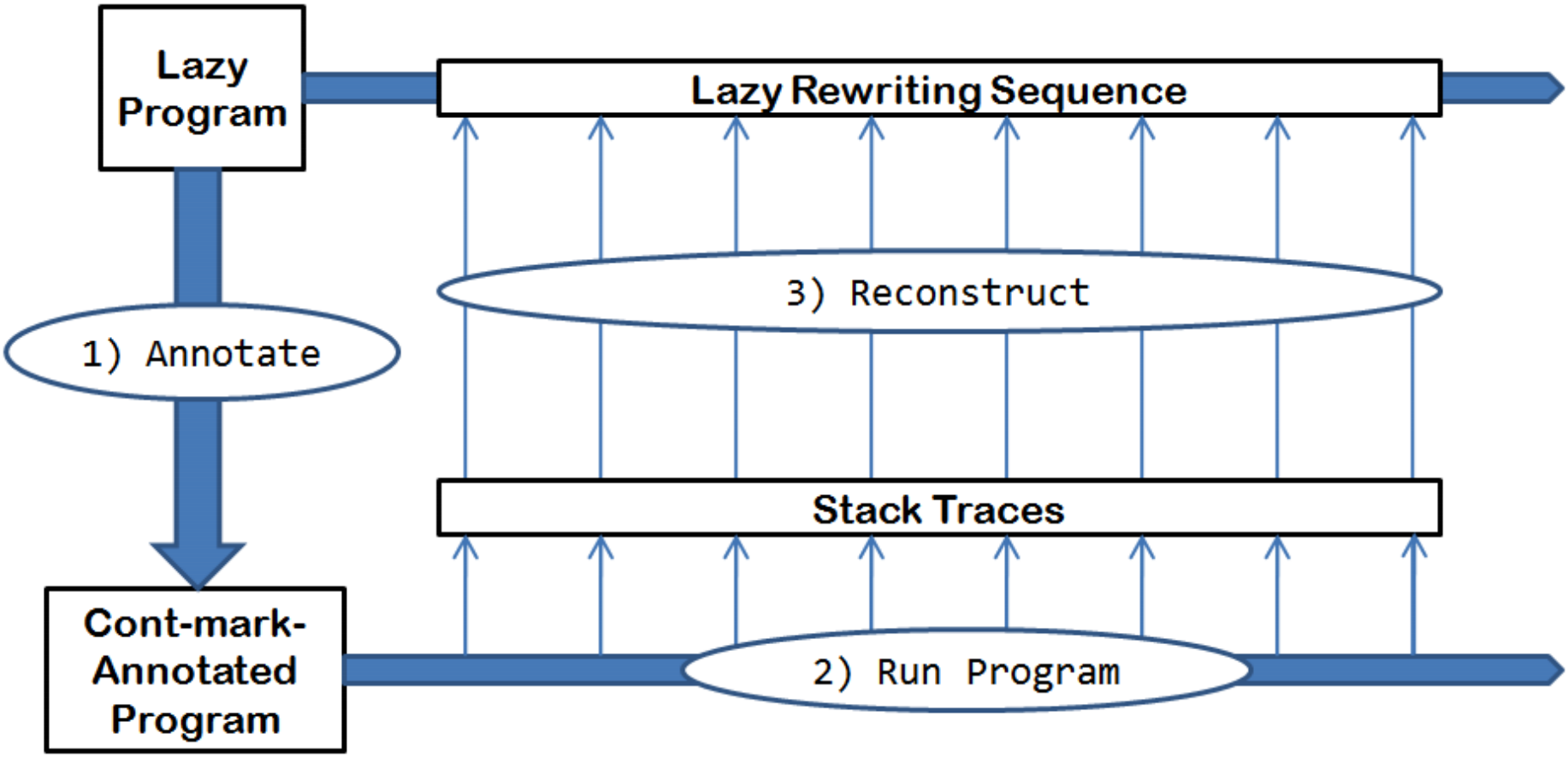


Continuation marks used in Racket implementation of:

stack tracer, stepper, debugger, profiler, exception handling,

dynamic binding, delimited continuations, web server

Stepper Architecture



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Correspondence exists between $\lambda_{need\|}$ and:

- Low-level semantics (i.e., Launchbury)
- Reduction semantics (i.e., Ariola et al.)

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- Advanced navigation features, breakpointing

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Summary

- New semantics for lazy evaluation: $\lambda_{need\|}$
  - Easy to understand and suitable for use in a debugger.
  - Equivalent to existing lazy semantics.
- Algebraic stepper for Lazy Racket, based on $\lambda_{need\|}$
  - Proven correct.
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Thanks!

`http://racket-lang.org/`