Ideas for Connecting Inductive Program Synthesis and Bidirectionalization

Janis Voigtländer

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PEPM'12

A small "test"

Which function is this?

$$
\begin{aligned}
\texttt{f}_1\ [a] &= a \\
\texttt{f}_1\ [a, b] &= b \\
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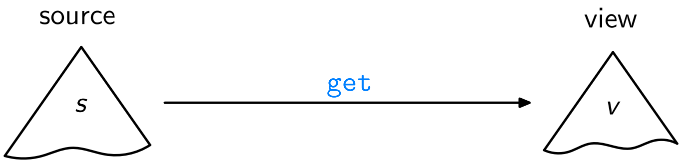
And this one?

$$\begin{aligned} \mathtt{f}_2\ [\,] &= [\,] \\ \mathtt{f}_2\ [a] &= [a] \\ \mathtt{f}_2\ [a, b] &= [b, a] \\ \mathtt{f}_2\ [a, b, c] &= [c, b, a] \end{aligned}$$

View-Update [Banc. & Sp., ACM TODS'81]



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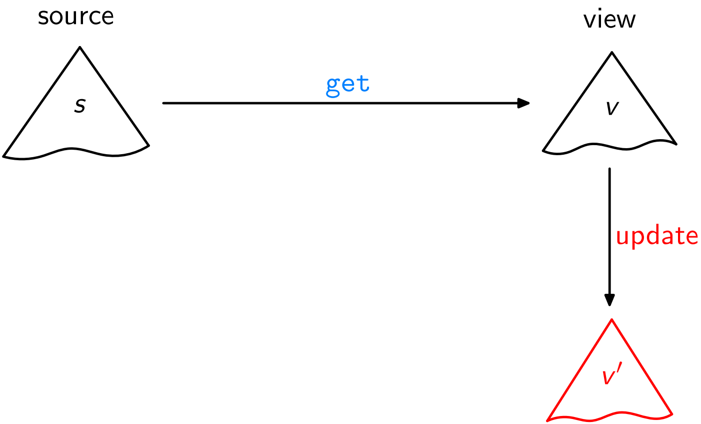

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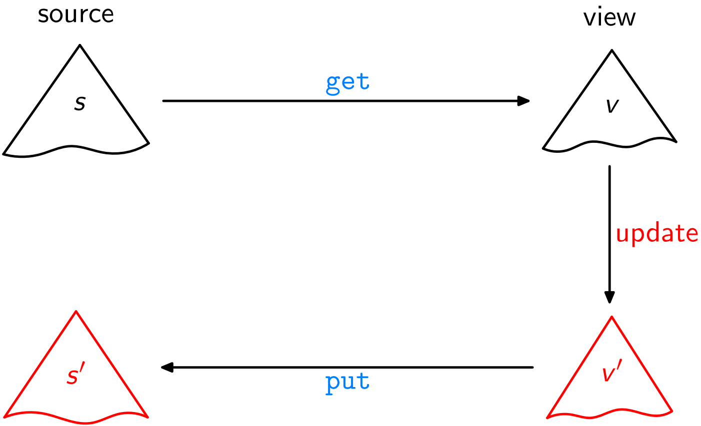

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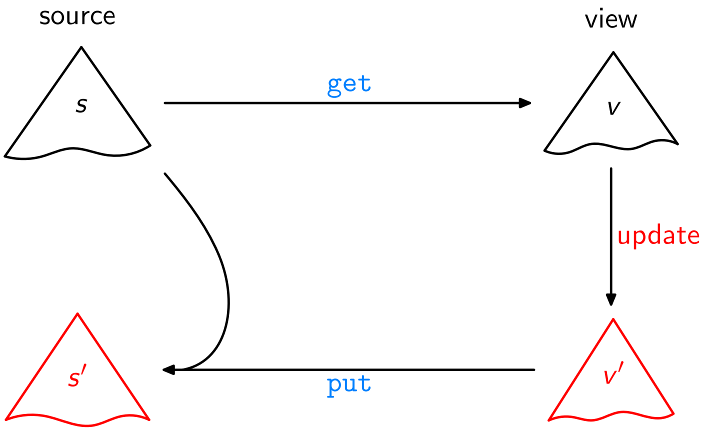

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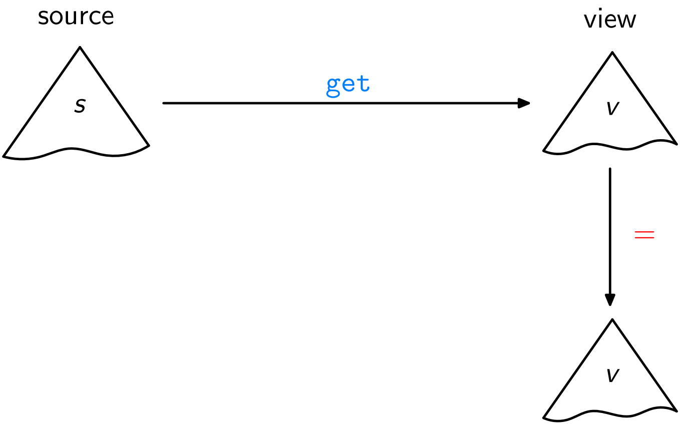
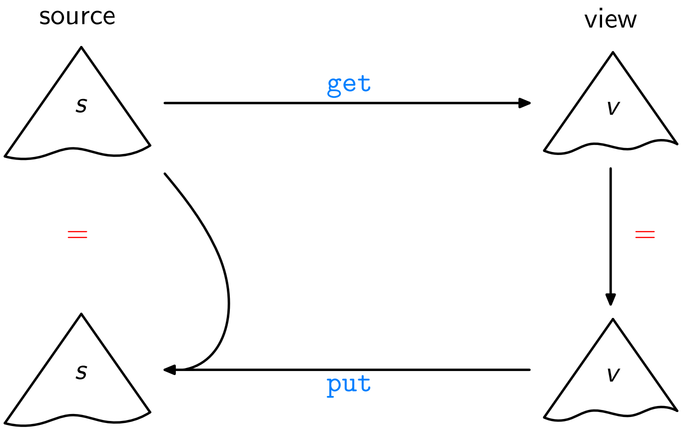


Acceptability / GetPut

View-Update [Banc. & Sp., ACM TODS'81]



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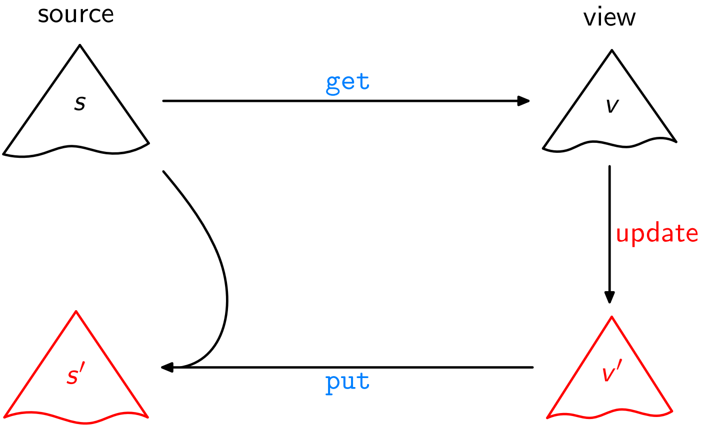
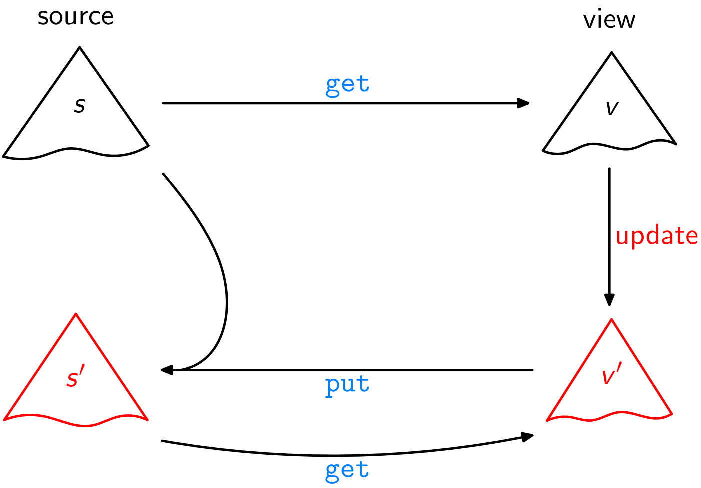


Consistency / PutGet

View-Update [Banc. & Sp., ACM TODS'81]



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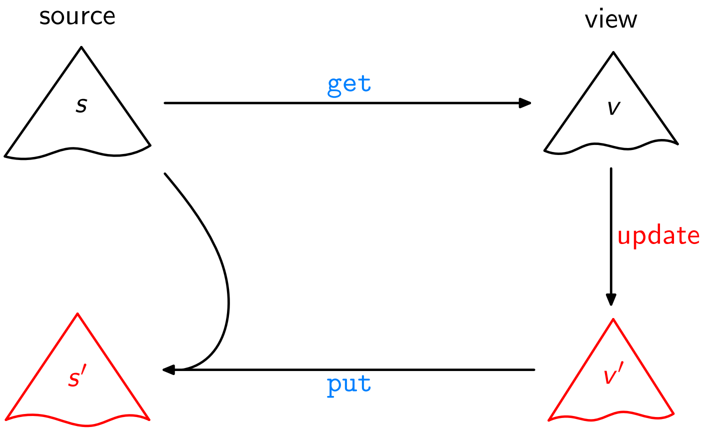

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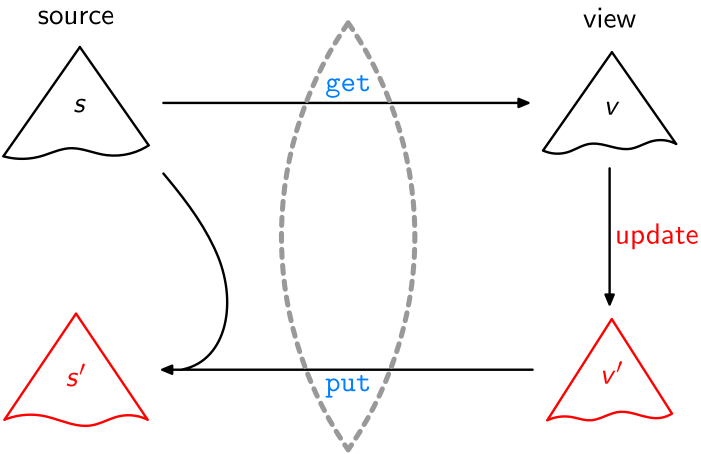

Lenses, DSLs

[Foster et al., ACM TOPLAS'07, . . .]

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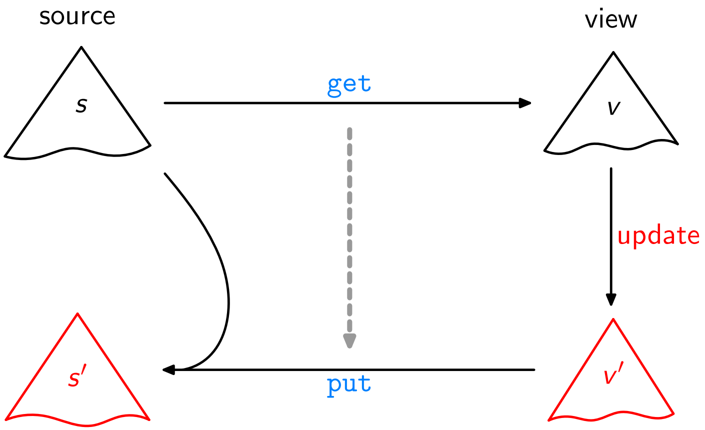


Bidirectionalization

[Matsuda et al., ICFP'07], [V., POPL'09], ...

Bidirectionalization (BX)

Examples:

$$\text{“abc”} \xrightarrow{\texttt{tail}} \text{“bc”}$$

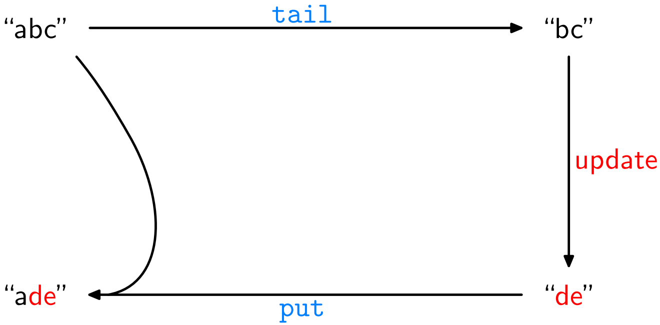
Bidirectionalization (BX)

Examples:

$$\begin{tikzcd} \text{“abc”} \arrow[r, "\texttt{tail}"] & \text{“bc”} \arrow[d, "\text{update}"] \\ & \text{“de”} \end{tikzcd}$$

Bidirectionalization (BX)

Examples:



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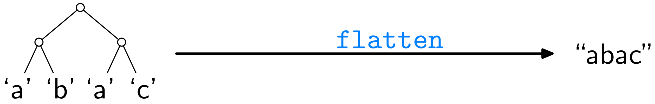

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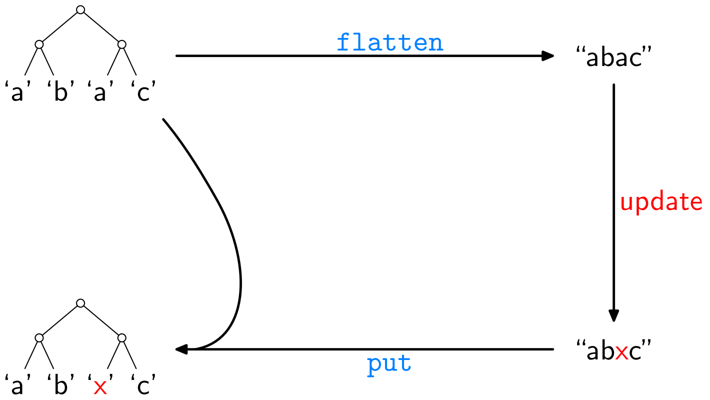

Nondeterminism / Choices to make

Let `get` = `sieve` with:

s	`""`	`"a"`	`"ab"`	`"abc"`	`"abcd"`	`"abcde"`
`sieve` s	`""`	`""`	`"b"`	`"b"`	`"bd"`	`"bd"`

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Then, for example:

`put "abcd" "xy"` $=$ `"axcy"`

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$\texttt{put}\ \texttt{"abcde"}\ \texttt{"xyz"} = \texttt{"axcyez"}$ or `"axcyez "`?

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`put "abcd" "x"` = `"axc"` or `"ax"` ? , or `"cx"` ?

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But "really intended":

$$\texttt{put}\ (x : xs)\ y = (y : xs)$$

A slightly more complex case, with recursion

Let `get` $=$ `init` with:

$$\begin{aligned} \texttt{init}\,[x] &= [\,] \\ \texttt{init}\,(x : xs) &= (x : (\texttt{init}\; xs)) \end{aligned}$$

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Possible, and correct:

$$\begin{aligned} \texttt{put}\ xs\ ys \mid \texttt{length}\ ys == (\texttt{length}\ xs) - 1 &= ys +\!\!+ [\texttt{last}\ xs] \\ \mid \texttt{otherwise} \qquad\qquad\qquad\qquad &= ys +\!\!+ \texttt{"\ "} \end{aligned}$$

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But intended:

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Problem: How to guide/control the possible choices?

Entry: Inductive Program Synthesis (IP)

Recall, I/O pairs for a function:

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From this, an IP system automatically generates the program:

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Or:

$$
\begin{aligned}
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\mathtt{f}_2\ [a] &= [a] \\
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\end{aligned}
$$

Again automatically generated:

$$
\begin{aligned}
\mathtt{f}_2\,[\,] &= [\,] \\
\mathtt{f}_2\,(x : xs) &= ((\mathtt{f}_3\,(x : xs)) : (\mathtt{f}_2\,(\mathtt{f}_4\,(x : xs)))) \\
\mathtt{f}_3\,[x] &= x \\
\mathtt{f}_3\,(x : xs) &= \mathtt{f}_3\,xs \\
\mathtt{f}_4\,[x] &= [\,] \\
\mathtt{f}_4\,(x : xs) &= (x : (\mathtt{f}_4\,xs))
\end{aligned}
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\texttt{f}_2\,[a, b, c] &= [c, b, a]
\end{aligned}
$$

Or, through provision of `snoc` as "background knowledge":

$$
\begin{aligned}
\texttt{f}_2\,[\,] &= [\,] \\
\texttt{f}_2\,(x : xs) &= \texttt{snoc}\,(\texttt{f}_2\; xs)\; x
\end{aligned}
$$

The master plan: BX + IP

Problem: Of the view-update laws

$$\texttt{put}\ xs\ (\texttt{get}\ xs) = xs$$

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only the first one directly delivers I/O pairs for `put`.

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But then one would synthesize:

$$\texttt{put}\ xs\ ys = xs$$

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<u>1. possible solution:</u> Enforce use of both arguments?

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First, on a simpler example, $\texttt{get} = \texttt{head}$:

$$
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To avoid $\texttt{put}\ xs\ y = xs$, insist on use of y, i.e., something like:

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To avoid $\texttt{put}\ xs\ y = xs$, insist on use of y, i.e., something like:

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Starting from this hypothesis, practically only one reasonable path of synthesis, with result something like:

$$\texttt{put}\ xs\ y = (y : (\texttt{tail}\ xs))$$

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For example:

$$\texttt{put}\ xs\ ys = (\texttt{take}\ (\texttt{length}\ ys)\ xs) +\!\!+ [\texttt{last}\ xs]$$

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Or:

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$$\texttt{put}\; xs\; ys = ys +\!\!+ [\texttt{last}\; xs]$$

Caution: Not every $\texttt{put}$ generated (like) above automatically satisfies $\texttt{get}\; (\texttt{put}\; xs\; ys) = ys$.

The master plan: BX + IP

On the more complex example, $\texttt{get} = \texttt{init}$:

$$\begin{aligned} \texttt{init}\,[x] &= [\,] \\ \texttt{init}\,(x : xs) &= (x : (\texttt{init}\; xs)) \end{aligned}$$

different "degrees" of use of *ys* in $\texttt{put}\; xs\; ys$ are possible.

For example:

$$\texttt{put}\; xs\; ys = (\texttt{take}\; (\texttt{length}\; ys)\; xs) \mathbin{+\!\!+} [\texttt{last}\; xs]$$

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Caution: Not every $\texttt{put}$ generated (like) above automatically satisfies $\texttt{get}\; (\texttt{put}\; xs\; ys) = ys$. (But it's okay, trust IP.)

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as well, "inversion" of `get`.

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In this case, agrees with the other suggestion ...

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On the more complex example, $\texttt{get} = \texttt{init}$:

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$$

Use of

$$\mathtt{init}^{-1}\ ys = \mathtt{snoc}\ ys\ \_$$

to provide, beside:

$$
\begin{aligned}
&\mathtt{put}\ [a]\quad\ [\,]\ \ = [a] \\
&\mathtt{put}\ [a, b]\ [a] = [a, b] \\
&\ldots
\end{aligned}
$$

also:

$$
\begin{aligned}
&\mathtt{put}\ [a]\quad\ [b] = [b, \_] \\
&\mathtt{put}\ [a, b]\ [\,]\ \ = [\_] \\
&\mathtt{put}\ [a, b]\ [c] = [c, \_] \\
&\ldots
\end{aligned}
$$

Conclusion / Outlook

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Conclusion / Outlook

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  - "hot topic" in various areas, including PL approaches
  - typical weakness: nondeterminism, and limited (or no) impact of programmer intentions
- Inductive Program Synthesis:
  - application of machine learning
  - detects/exploits regularities
  - hypothesis: captures programmer intentions
- Connection:
  - inductive program synthesis as a "helper"
  - either naively as a black box, or deeper integration
  - further ideas: I/O pairs per parametricity of `get`;
    user impact through ad-hoc I/O pairs or provision of background knowledge;
    ...

References I

F. Bancilhon and N. Spyratos.
Update semantics of relational views.
ACM Transactions on Database Systems, 6(3):557–575, 1981.

J.N. Foster, M.B. Greenwald, J.T. Moore, B.C. Pierce, and A. Schmitt.
Combinators for bidirectional tree transformations: A linguistic approach to the view-update problem.
ACM Transactions on Programming Languages and Systems, 29(3):17, 2007.

S. Katayama.
Systematic search for lambda expressions.
In *Trends in Functional Programming 2005, Revised Selected Papers*, pages 111–126. Intellect, 2007.

References II

E. Kitzelmann and U. Schmid.
Inductive synthesis of functional programs: An explanation based generalization approach.
Journal of Machine Learning Research, 7:429–454, 2006.

K. Matsuda, Z. Hu, K. Nakano, M. Hamana, and M. Takeichi.
Bidirectionalization transformation based on automatic derivation of view complement functions.
In *International Conference on Functional Programming, Proceedings*, pages 47–58. ACM Press, 2007.

J. Voigtländer.
Bidirectionalization for free!
In *Principles of Programming Languages, Proceedings*, pages 165–176. ACM Press, 2009.