Combining Syntactic and Semantic Bidirectionalization

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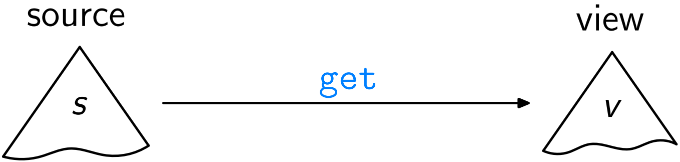
[2]NII Tokyo

[3]Tohoku University

[4]University of Oxford

ICFP'10

Bidirectional Transformation



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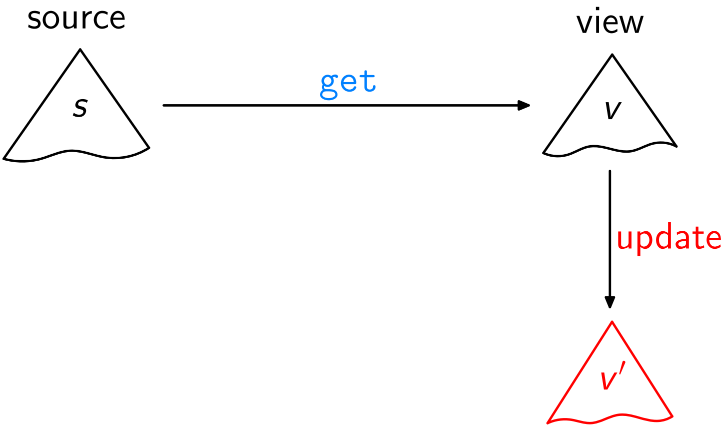

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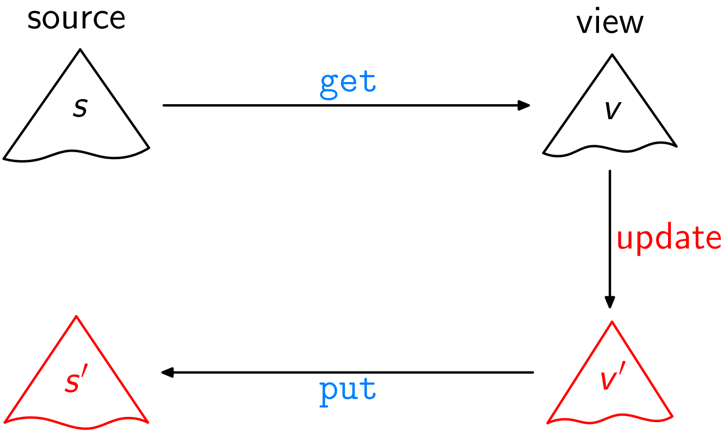

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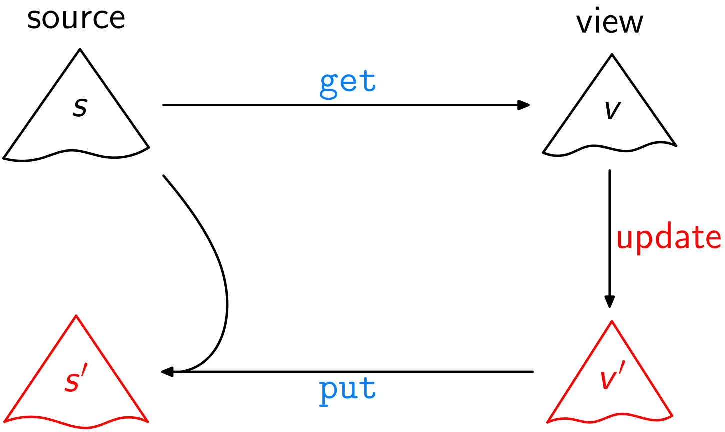

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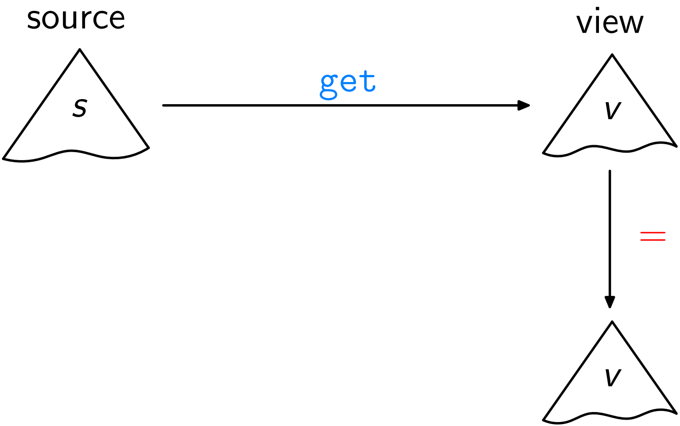
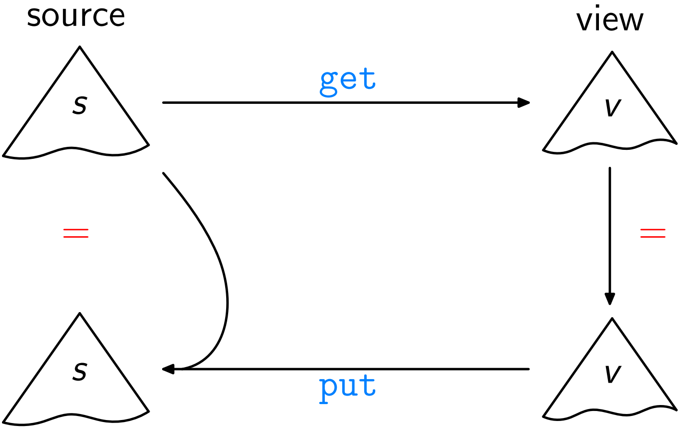


Acceptability / GetPut

Bidirectional Transformation



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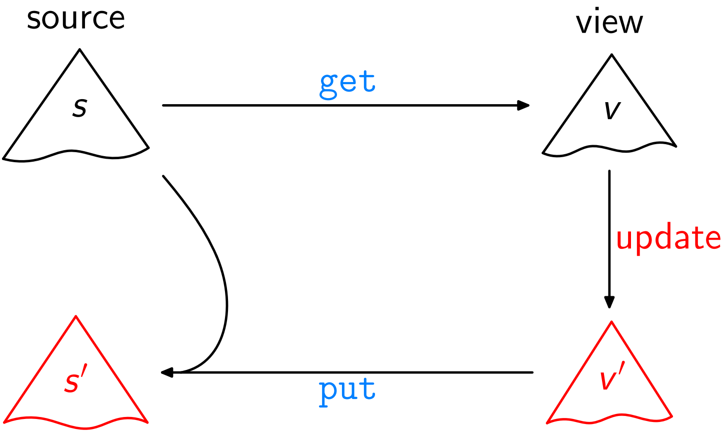

Consistency / PutGet

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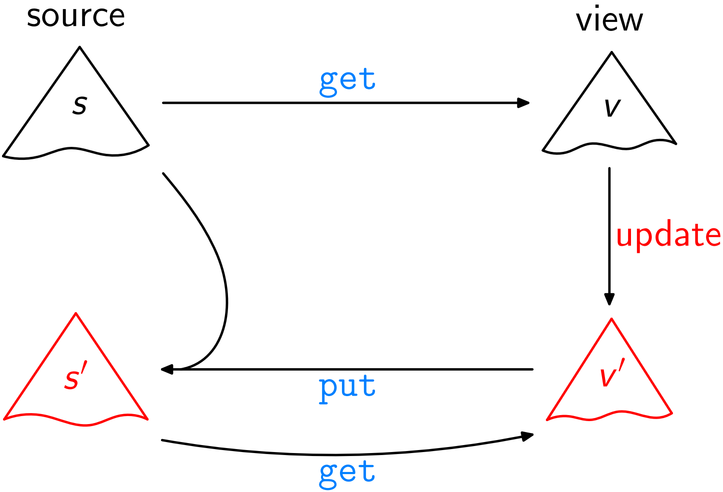

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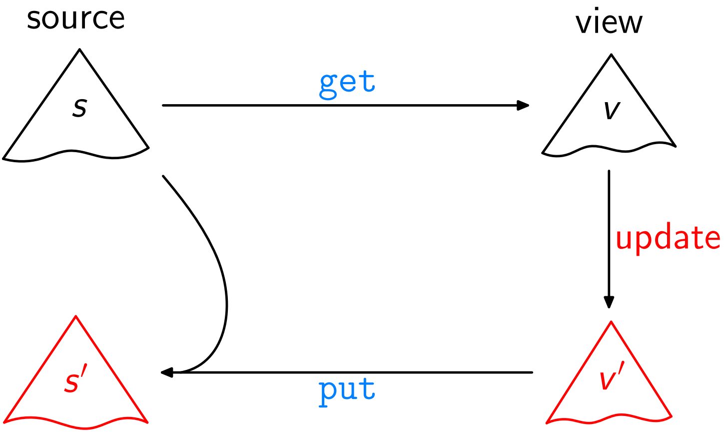

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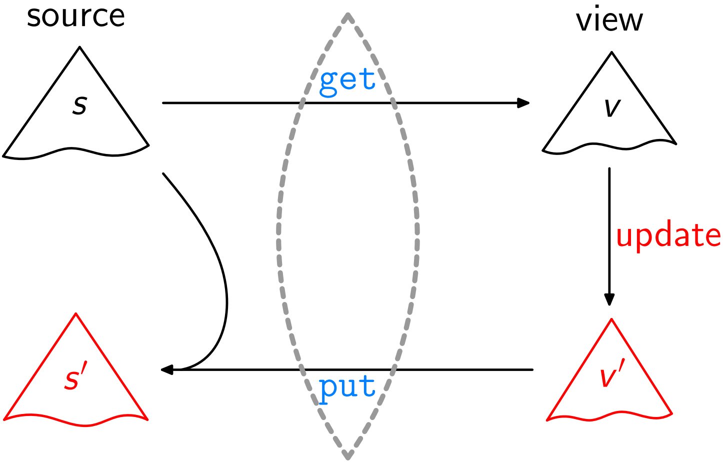
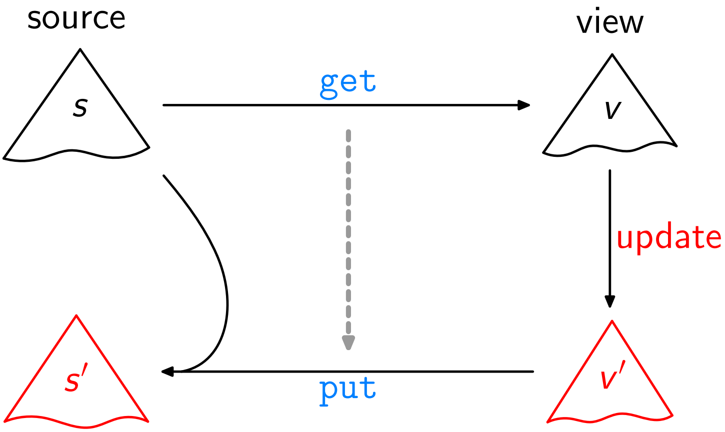


Lenses, DSLs

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

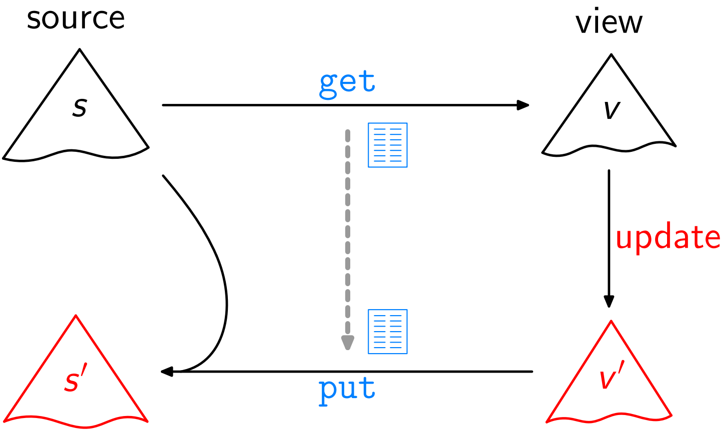
Bidirectional Transformation



Bidirectionalization

[Matsuda et al., ICFP'07]

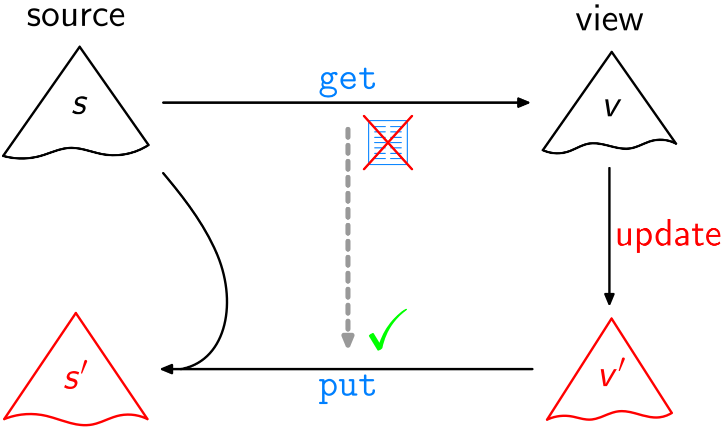
Bidirectional Transformation



Syntactic Bidirectionalization

[Matsuda et al., ICFP'07]

Bidirectional Transformation



Semantic Bidirectionalization

[V., POPL'09]

Semantic Bidirectionalization

Idea: Have higher-order function `bff`[†] such that any `get` and `bff get` satisfy GetPut, PutGet, ...

[†] "<u>B</u>idirectionalization <u>f</u>or <u>f</u>ree!"

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Examples:

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

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Examples:

$$
\begin{tikzcd}
\text{“abc”} \arrow[rr, "\texttt{tail}"] \arrow[d, bend left] & & \text{“bc”} \arrow[d, "\text{update}"] \\
\text{“ade”} & & \text{“de”} \arrow[ll, "\texttt{bff tail}"]
\end{tikzcd}
$$

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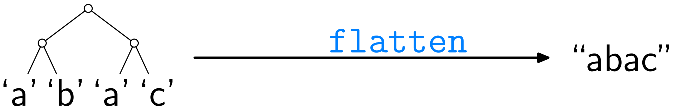

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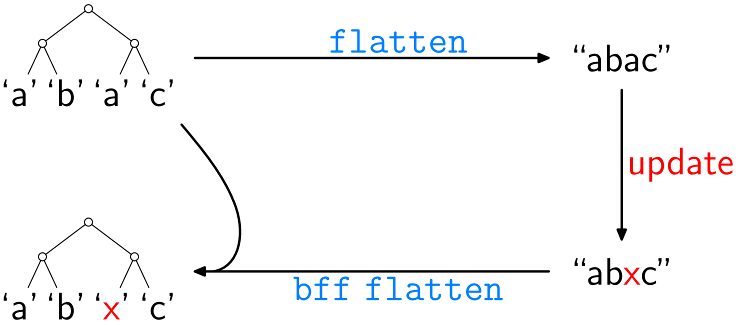

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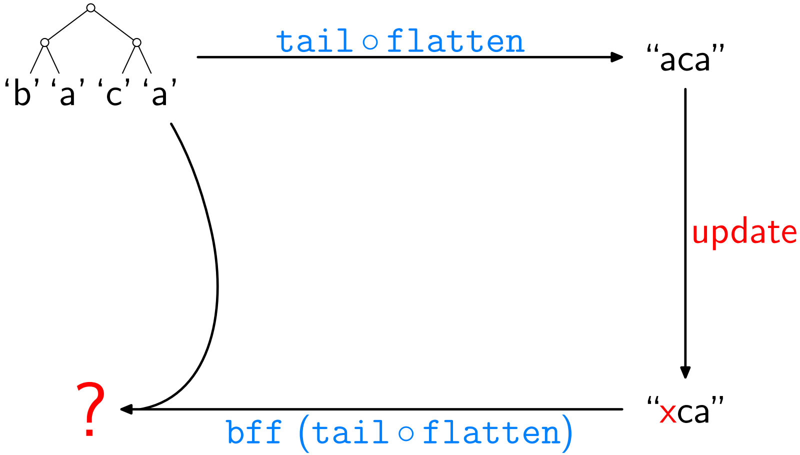
The Semantic Approach by Example



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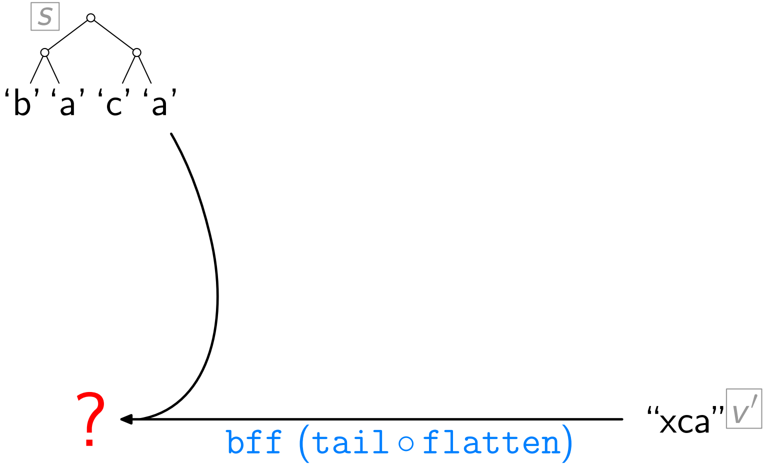

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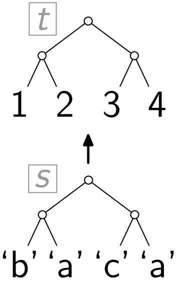

$1 \rightarrow$ 'b'
$2 \rightarrow$ 'a'
$3 \rightarrow$ 'c'
$4 \rightarrow$ 'a'

"xca" v'

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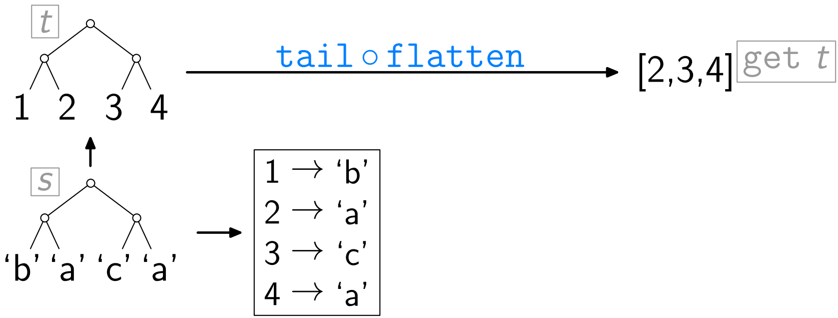

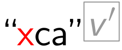

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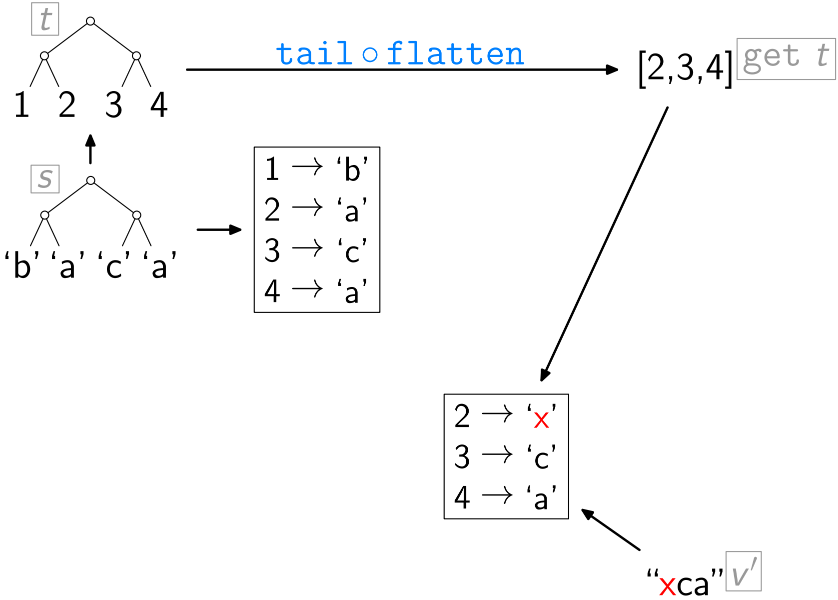

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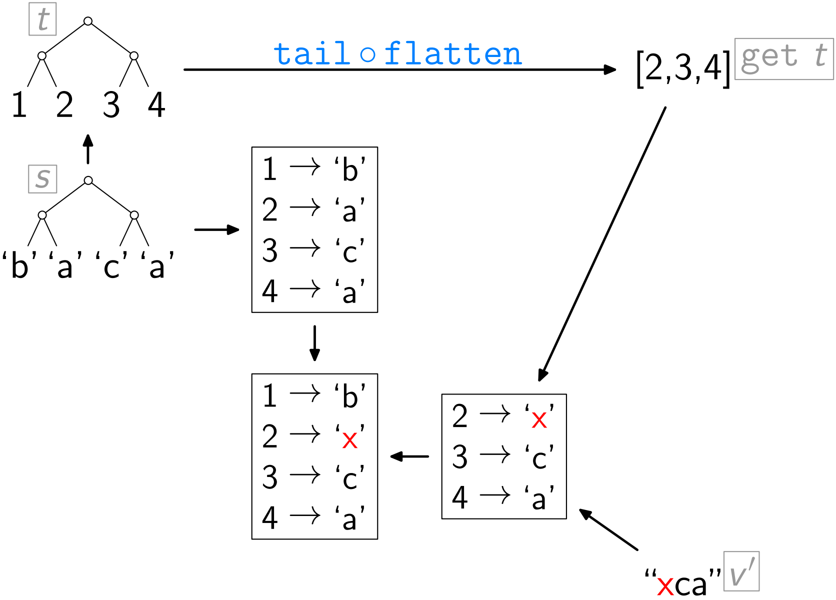

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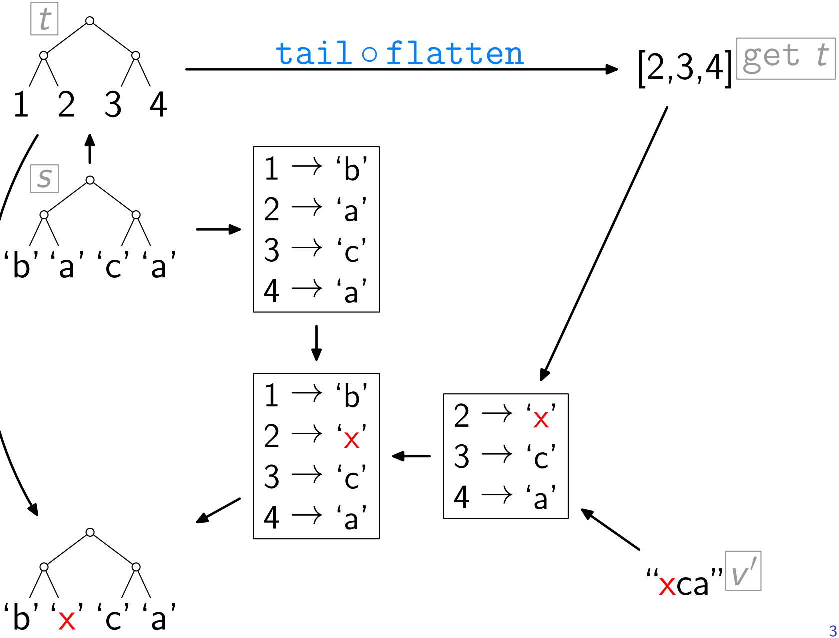

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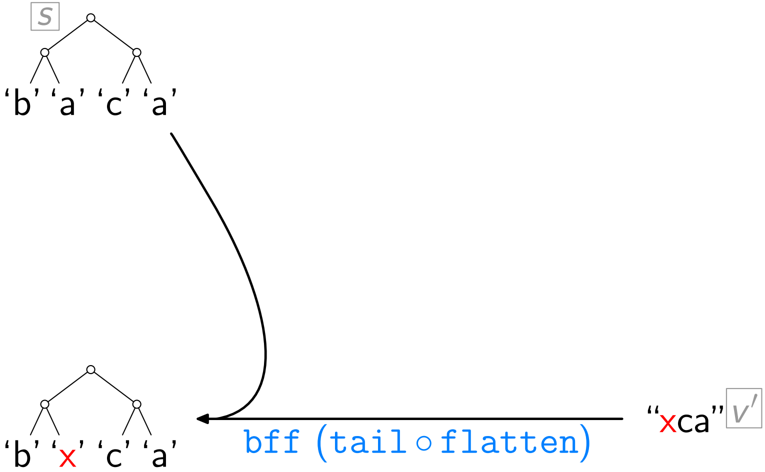

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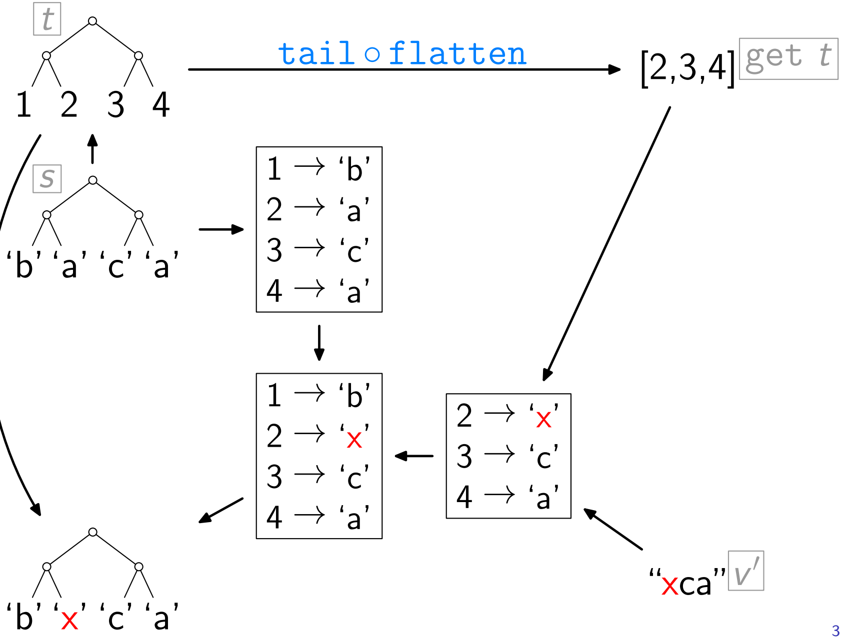

“Status Quo”

[V., POPL’09]:

- very lightweight, easy access to bidirectionality
- proofs by free theorems [Wadler, FPCA’89]
- major problem: rejects shape-changing updates

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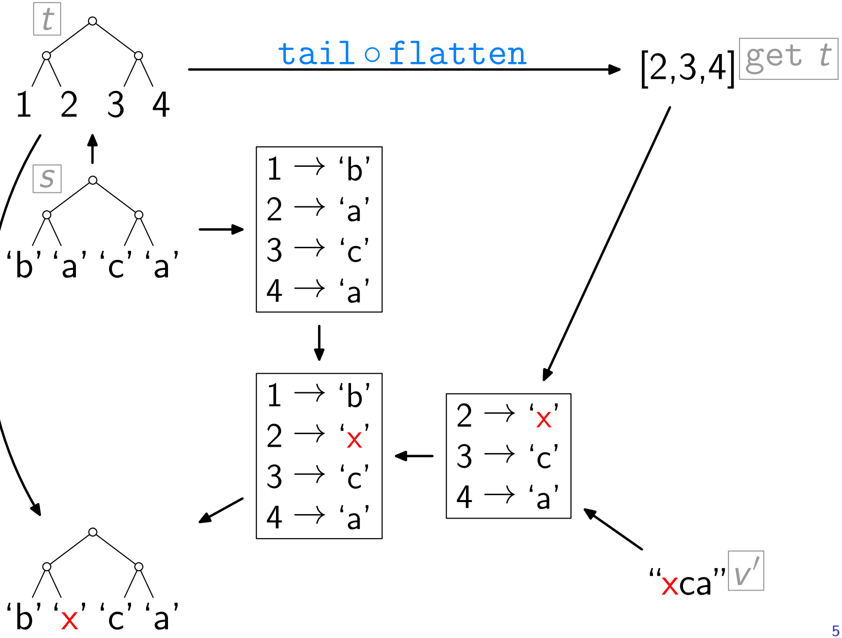
Here:

- synthesis of the two techniques
- inherits limitations in program coverage from both
- strictly better in terms of updatability than either

More Shape-Flexibility



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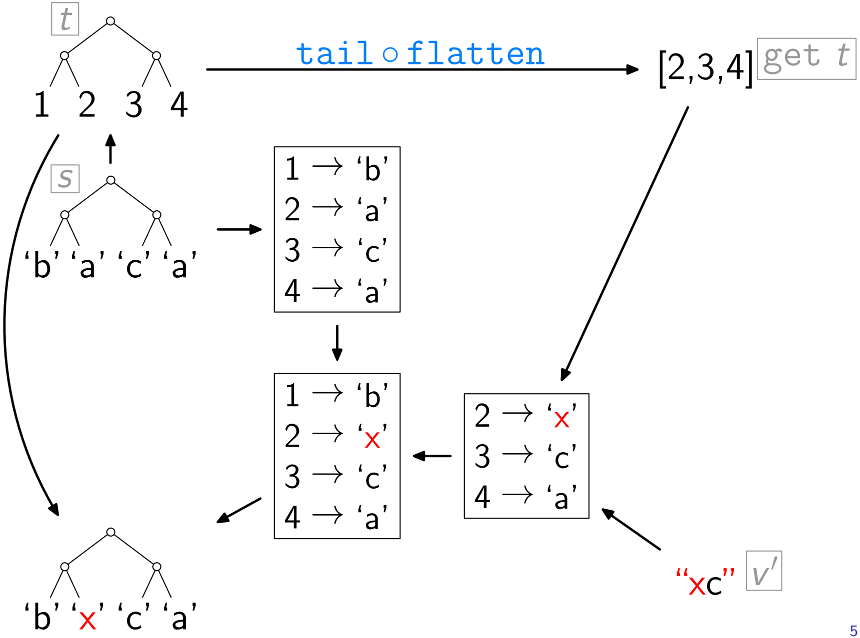

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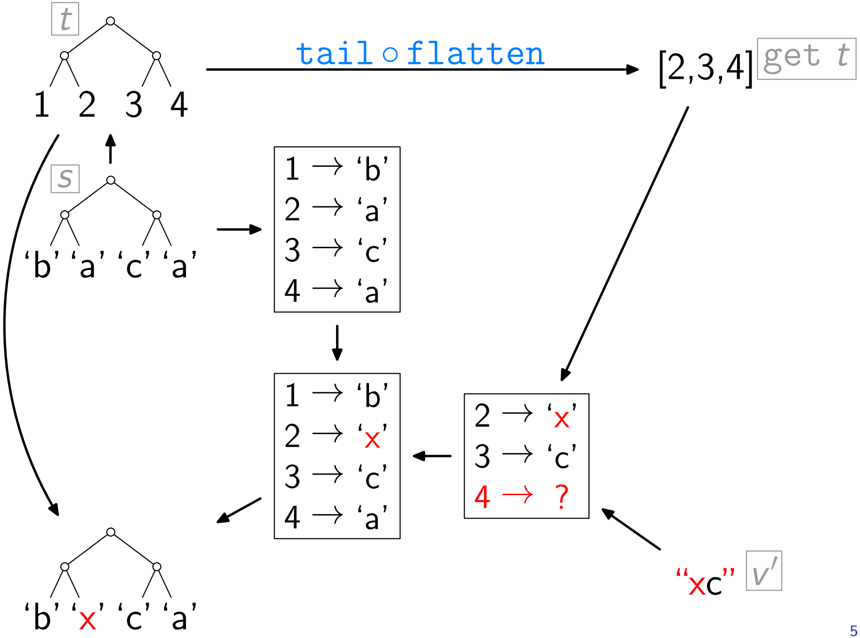

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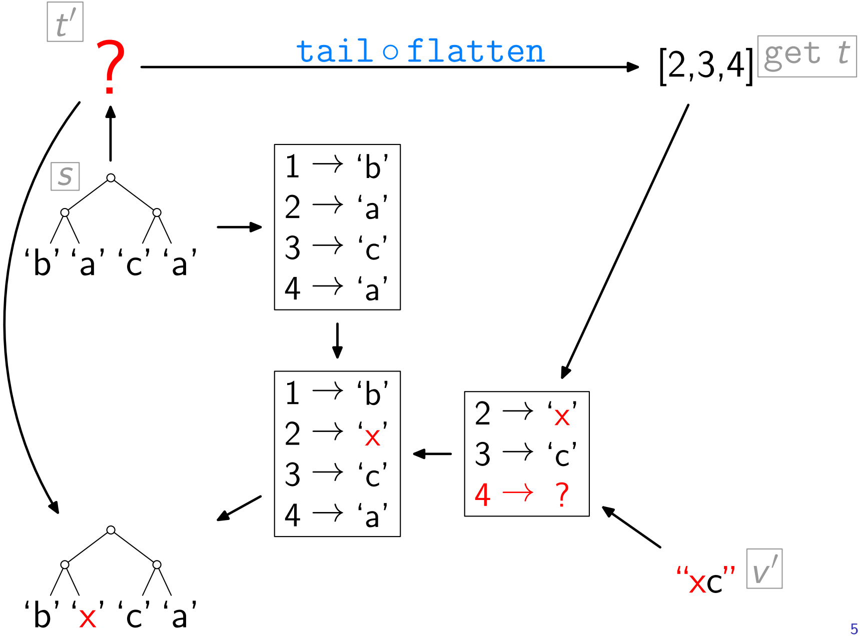

Expectations on $\mathbf{t}'$

Let σ be a function which given a data structure computes a representation of its shape.

Then we want:

1. $\sigma(\texttt{get}\ t') = \sigma(v')$
2. if $\sigma(v') = \sigma(\texttt{get}\ s)$, then $\sigma(t') = \sigma(s)$

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Key Idea: Abstraction!

Find sget such that:

$$
\begin{tikzcd}
\circ \arrow[r, "\texttt{get}"] \arrow[d, "\sigma"'] & \circ \arrow[d, "\sigma"] \\
\circ \arrow[r, "\texttt{sget}"'] & \circ
\end{tikzcd}
$$

“Bootstrapping”

For `sget`, find `sput` such that GetPut and PutGet hold:

$$
\begin{tikzcd}
\circ \arrow[r, "\texttt{sget}"] \arrow[d, bend left, "="'] & \circ \arrow[d, "="] \\
\circ & \circ \arrow[l, "\texttt{sput}"]
\end{tikzcd}
\qquad\qquad
\begin{tikzcd}
\circ \arrow[r, "\texttt{sget}"] \arrow[d, bend left] & \circ \arrow[d, "?"] \\
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\end{tikzcd}
$$

Then, set t' such that:

$$
\begin{tikzcd}
\sigma(s) \arrow[d, bend left] & \\
\sigma(t') & \sigma(v') \arrow[l, "\mathtt{sput}"']
\end{tikzcd}
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Expectations on t'

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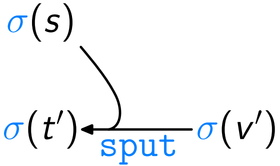

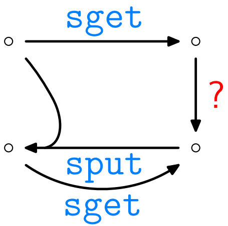

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follows:

$$\begin{tikzcd} \sigma(s) \arrow[r, "\mathtt{sget}"] \arrow[d, bend left] & \circ \arrow[d, "?"] \\ \sigma(t') \arrow[r, bend right, "\mathtt{sget}"'] & \sigma(v') \arrow[l, "\mathtt{sput}"'] \end{tikzcd}$$

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\end{tikzcd}
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\begin{tikzcd}
t' \arrow[r, "\mathtt{get}"] \arrow[d, "\sigma"'] & \circ \arrow[d, "\sigma"] \\
\circ \arrow[r, "\mathtt{sget}"'] & \circ
\end{tikzcd}$$

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\circ \arrow[r, "\texttt{sget}"] \arrow[d, bend left, phantom, ""] \arrow[d, bend left] \arrow[d, phantom, "\color{red}{=}"', shift right=3ex] & \circ \arrow[d] \arrow[d, phantom, "\color{red}{=}", shift left=3ex] \\
\circ & \circ \arrow[l, "\texttt{sput}"]
\end{tikzcd}$$

follows:

$$\begin{tikzcd}
\sigma(s) \arrow[r, "\texttt{sget}"] \arrow[d, bend left] \arrow[d, phantom, "\color{red}{=}"', shift right=3ex] & \circ \arrow[d] \arrow[d, phantom, "\color{red}{=}", shift left=3ex] \\
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From:

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\begin{tikzcd}
\sigma(s) \arrow[r, "\texttt{sget}"] \arrow[d, phantom, "="] & \circ \arrow[d] \arrow[d, phantom, shift left=4ex, "="] \\
\sigma(t') & \sigma(v') \arrow[l, "\texttt{sput}"]
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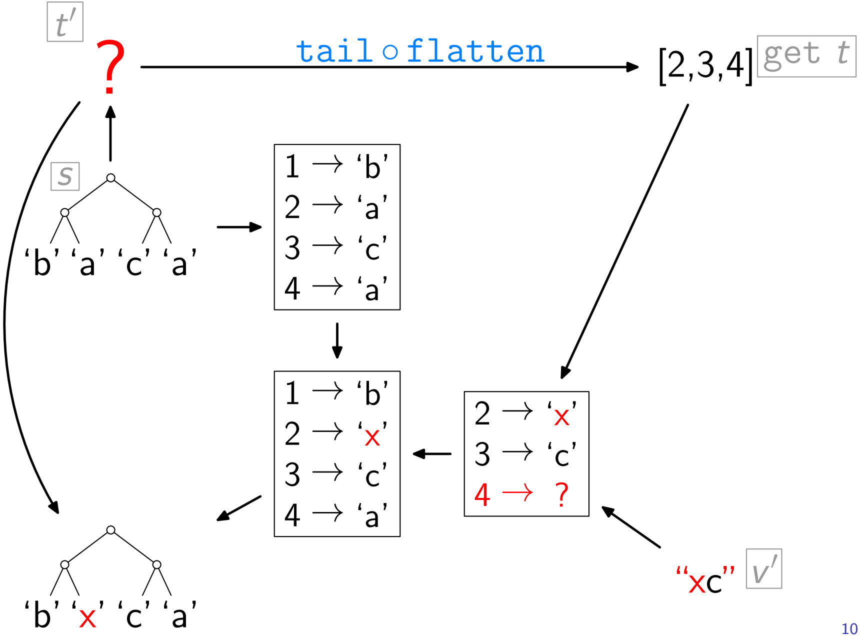

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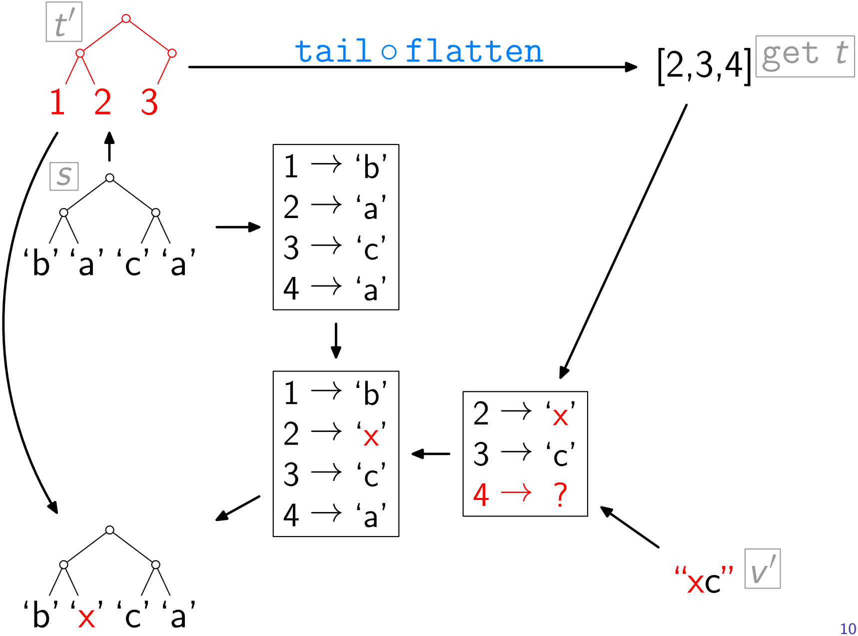

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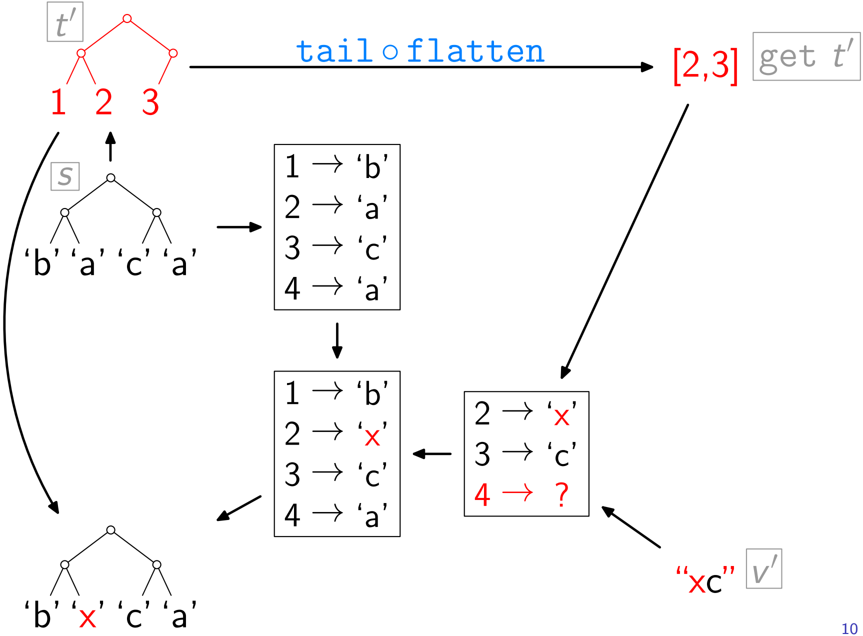

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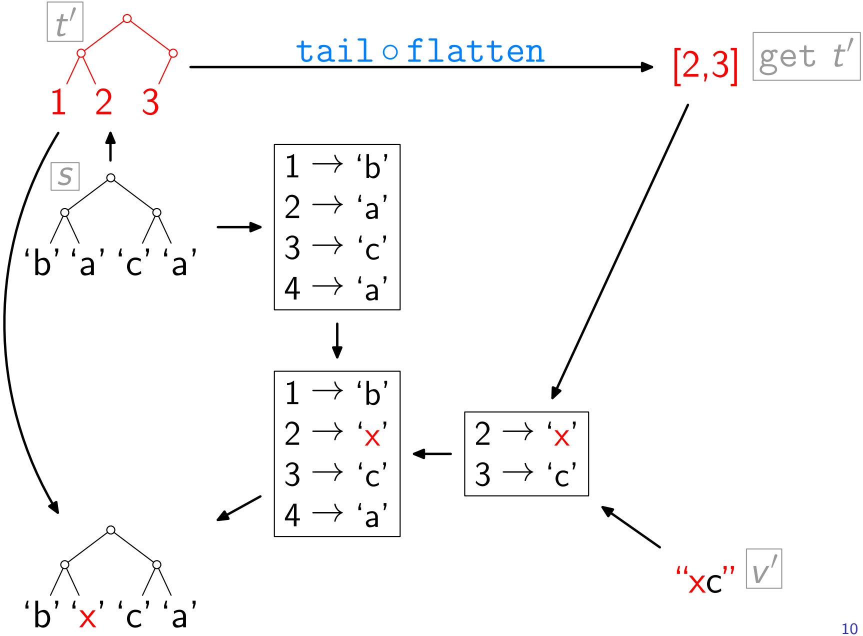

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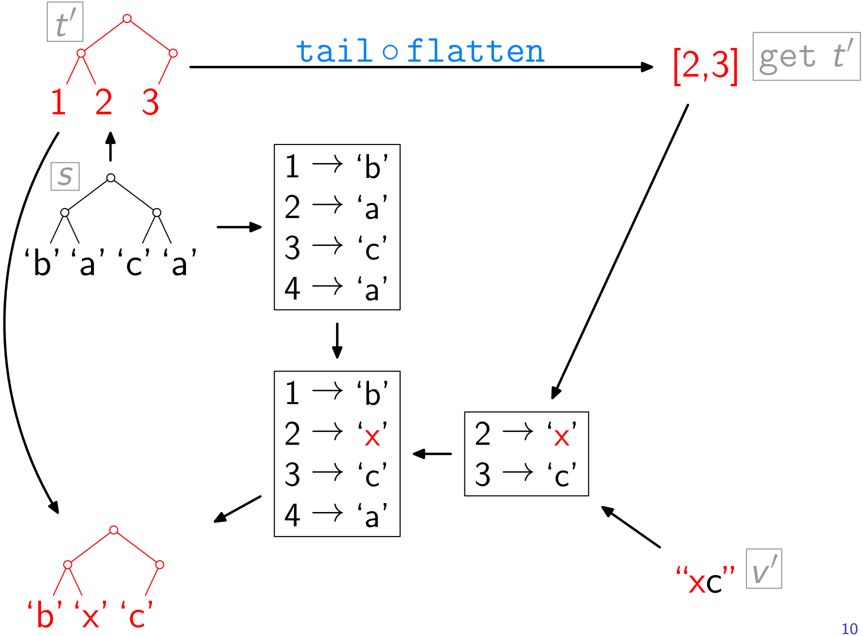

Essential Ingredients

The crucial point is to find `sget` with:

$$\begin{tikzcd} \circ \arrow[r, "\texttt{get}"] \arrow[d, "\sigma"'] & \circ \arrow[d, "\sigma"] \\ \circ \arrow[r, "\texttt{sget}"'] & \circ \end{tikzcd}$$

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as well as sput such that:

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syntactic abstraction

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syntactic abstraction

as well as `sput` such that:

$$\begin{tikzcd} \circ \arrow[r, "\texttt{sget}"] \arrow[d, bend left, "="'] & \circ \arrow[d, "="] \\ \circ & \circ \arrow[l, "\texttt{sput}"] \end{tikzcd} \qquad \begin{tikzcd} \circ \arrow[r, "\texttt{sget}"] \arrow[d, bend left] & \circ \arrow[d, "?"] \\ \circ \arrow[r, bend right, "\texttt{sget}"'] & \circ \arrow[l, "\texttt{sput}"] \end{tikzcd}$$

[M. et al., ICFP'07]

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&\texttt{get} :: [\alpha] \to [\alpha] \\
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\begin{array}{l}
\texttt{sput}\ 0 \qquad\quad 0 \qquad\qquad = 0 \\
\texttt{sput}\ 1 \qquad\quad 0 \qquad\qquad = 1 \\
\texttt{sput}\ (n+2)\ 0 \qquad\qquad = \cdots \\
\texttt{sput}\ n \qquad\quad (v'+1) = \cdots
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  - lightweight, "as a library"
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  - "constant-complement" [Banc. & Sp., TODS'81]
- Combination per "Separation of Concerns":
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  - treat shape via syntactic approach
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- (More) future work: general types, type classes

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