Bidirectional Transformation and Its Application to Dependable Document Construction

Zhenjiang Hu and Masato Takeichi

Department of Mathematical Informatics
The University of Tokyo

December 7, 2007

(Joint Work with Y. Hayashi, D. Liu, S.C. Mu and K. Nakano)

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Outline

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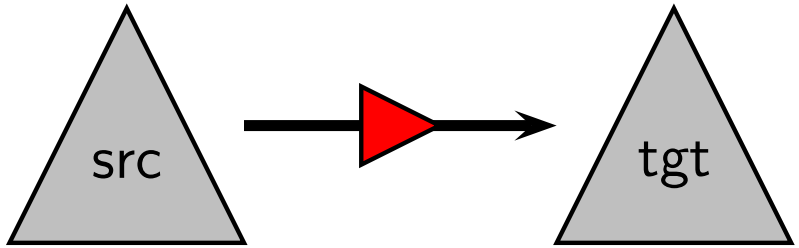

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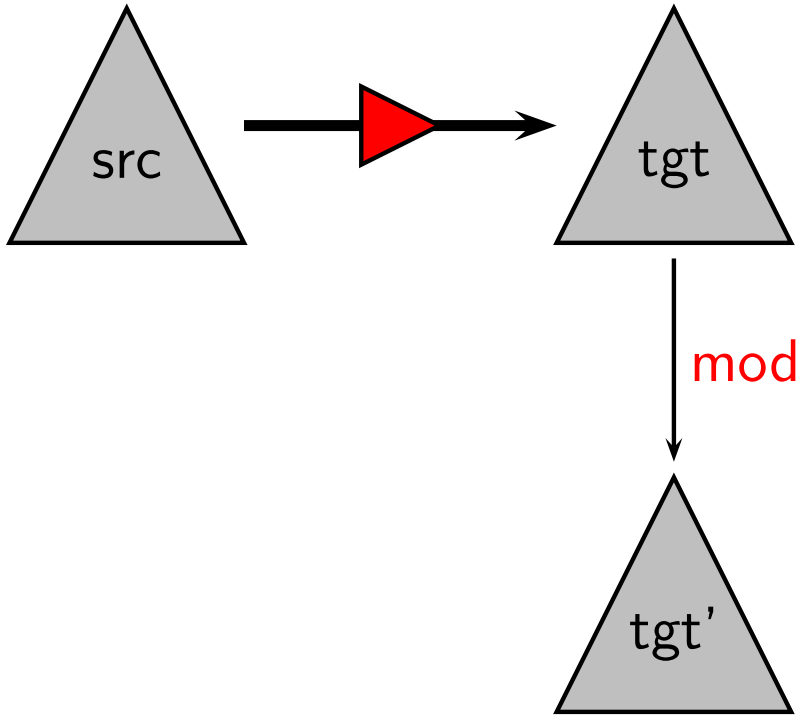

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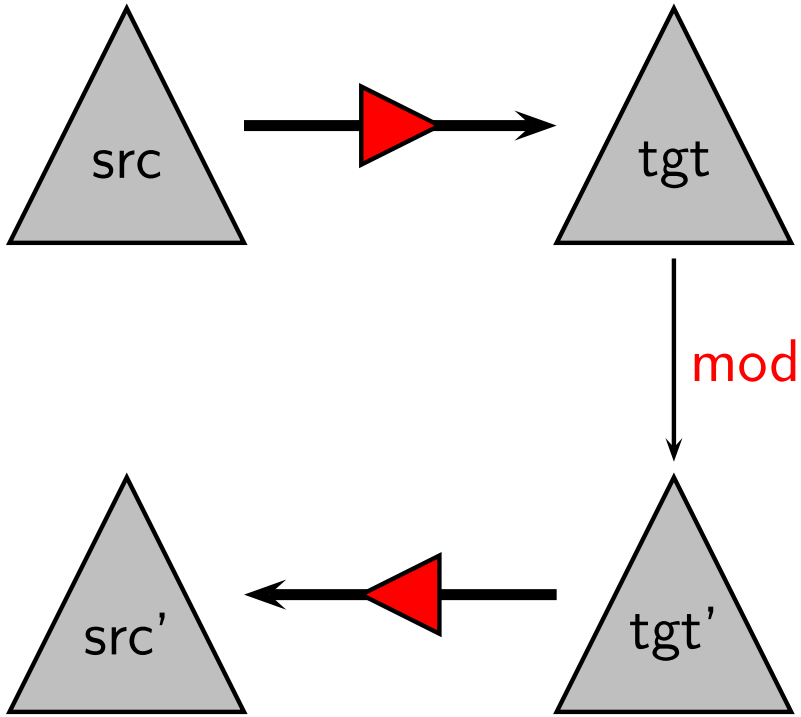

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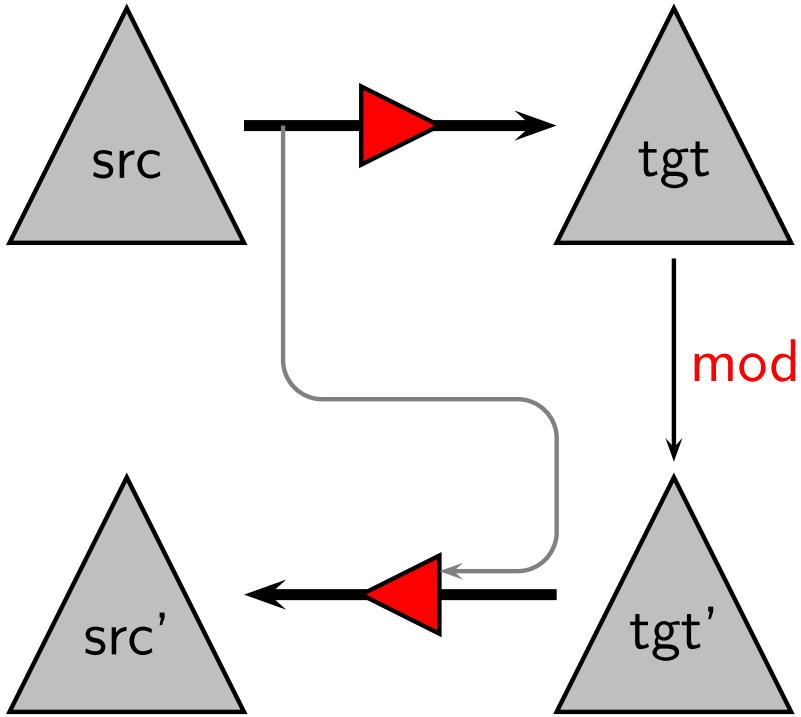

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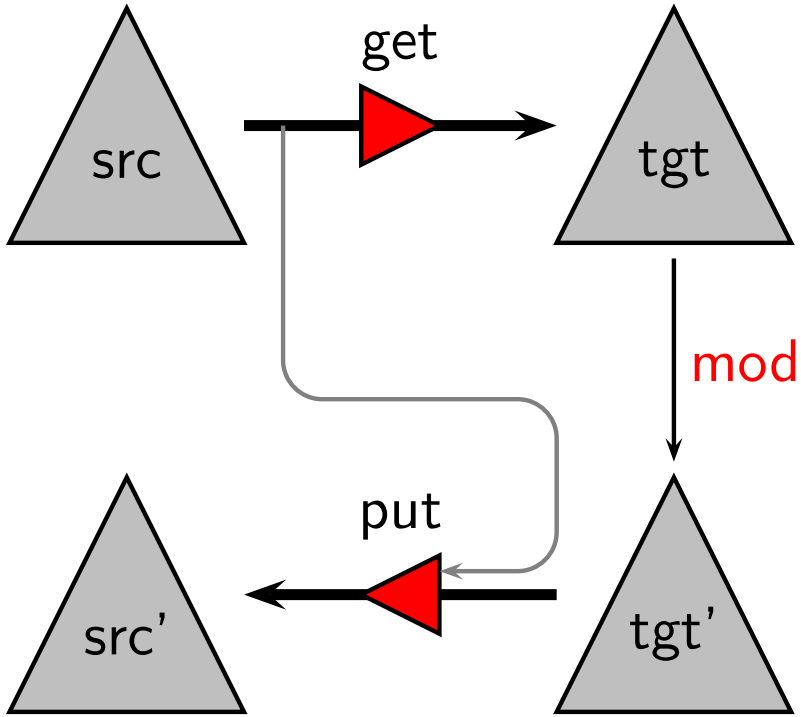
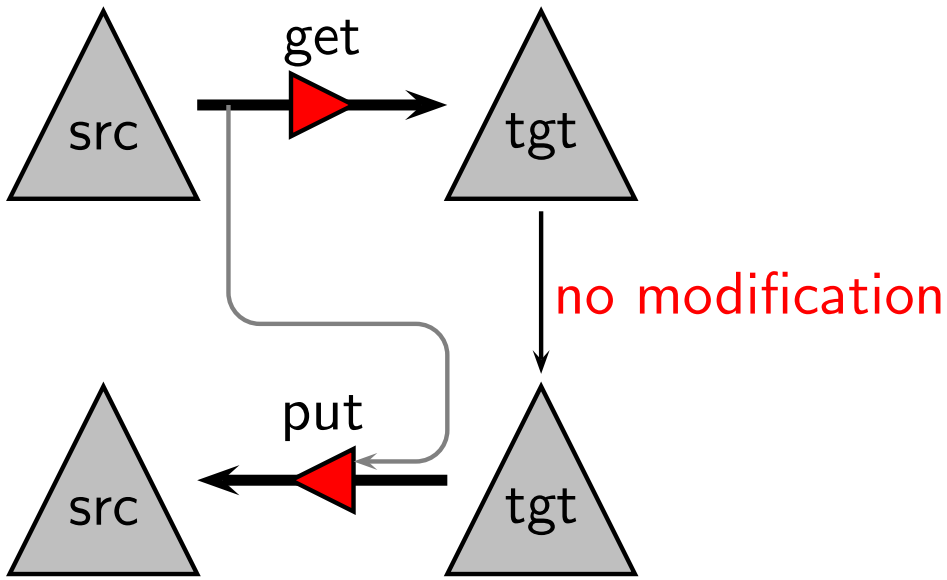


It consists of a pair of transformations: forward and backward.

Stability

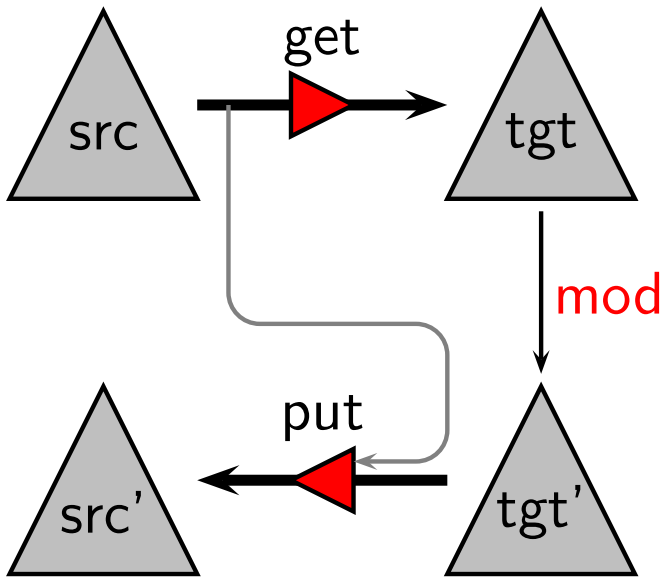
No change on the target implies no change on the source.



$$\mathrm{put}(\mathrm{get}(s), s) = s$$

Reflectivity

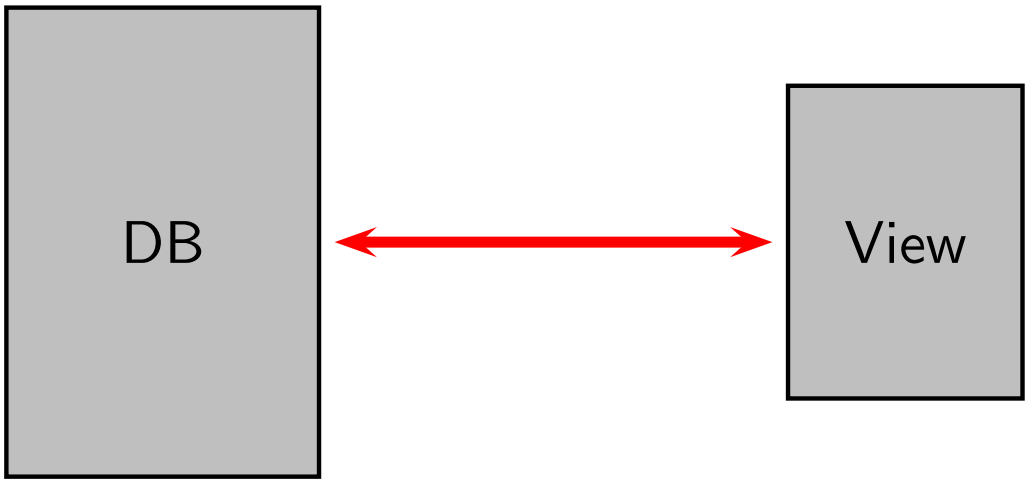
Permitted changes on the target should be reflected to the source.



$$\mathrm{get}(\mathrm{put}(t', s)) = t'$$

View Updating

Reflect changes on the view to the original relational database.



Ref: many studies in the database community
[Bancilhon&Spyratos:81, Dayal&Bernstein, Gottlob et. al.:88]

Replicated Data Synchronization

Synchronization of data in different formats.

Ref: the Homony project in Univ. of Pennsylvania
[Pierce et. al: POPL'05, PODS'06, POPL'08].

Outline

Document Engineering

Document engineering is concerned with principles, tools and processes that improve our ability to create, manage, and maintain documents.

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Documents:

- Document Source
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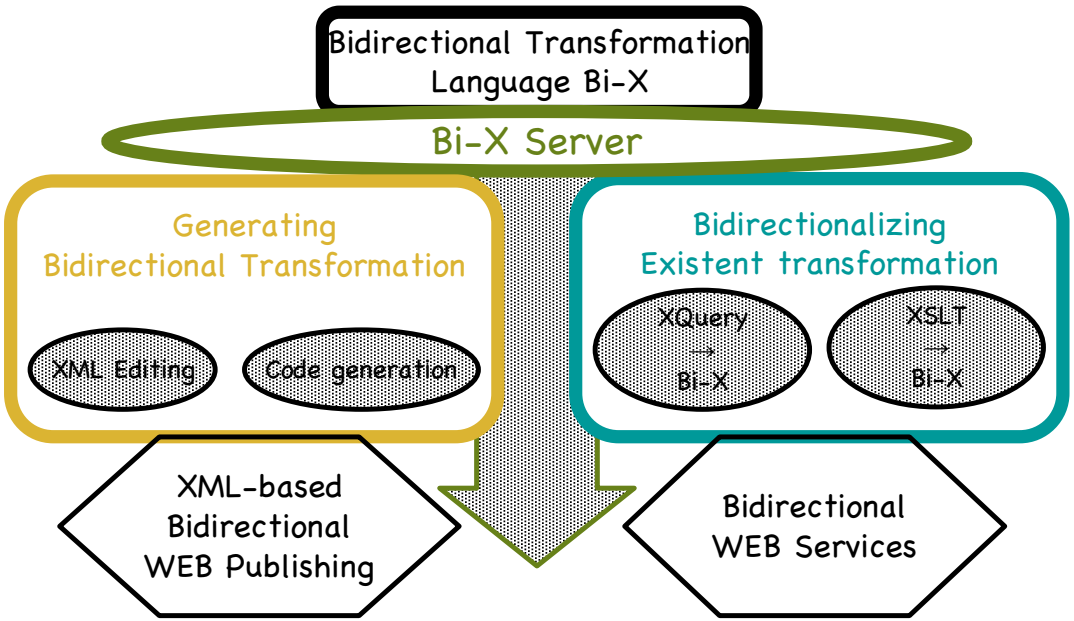
Documents are of much simpler structures than softwares.

The PSD Project

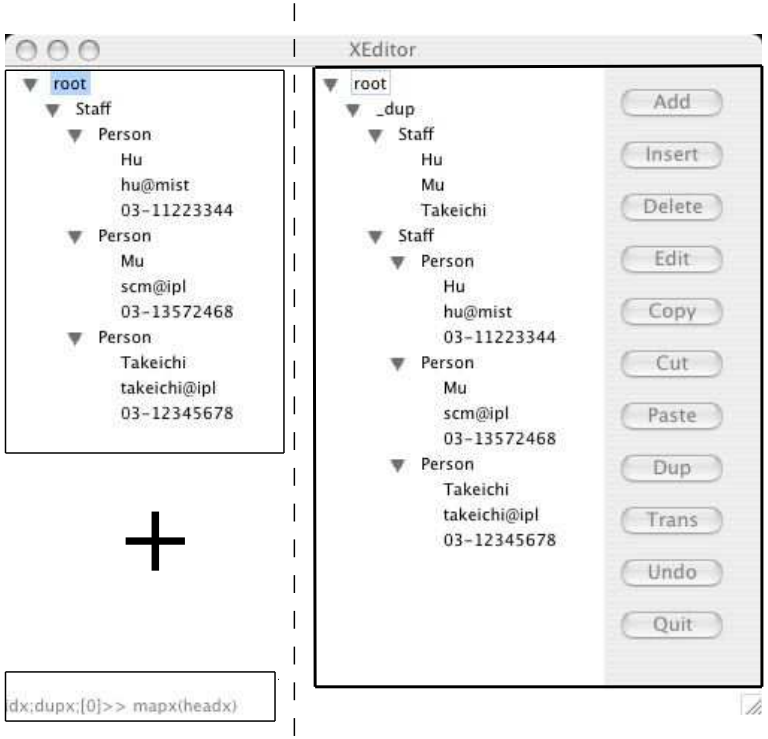
A bidirectional transformation framework for supporting formal creation and maintenance of documents.



Motivation: Applying program transformation techniques to document transformation.

Document Creation

XEditor: Document Construction = View Editing

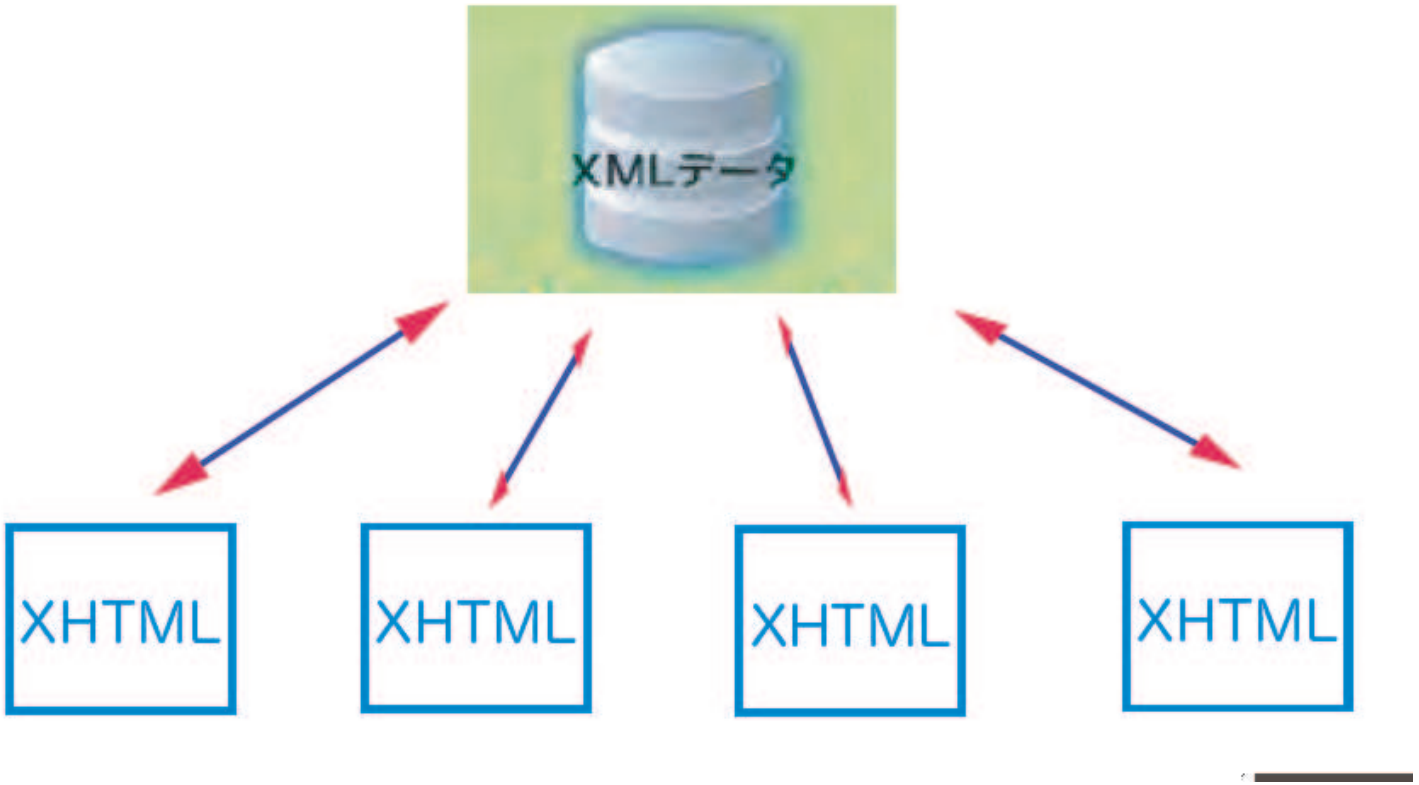


XML + Transformation in X/Inv ⇐ Editing on view

Ref: [MPC'04, PEPM'04, HOSC:07].

Document Maintenance

Vu-X: update web pages on browsers in the WYSIWYG manner.



Ref: [JSSST'06, JSSST'07, PEPM'07, APWeb'07].

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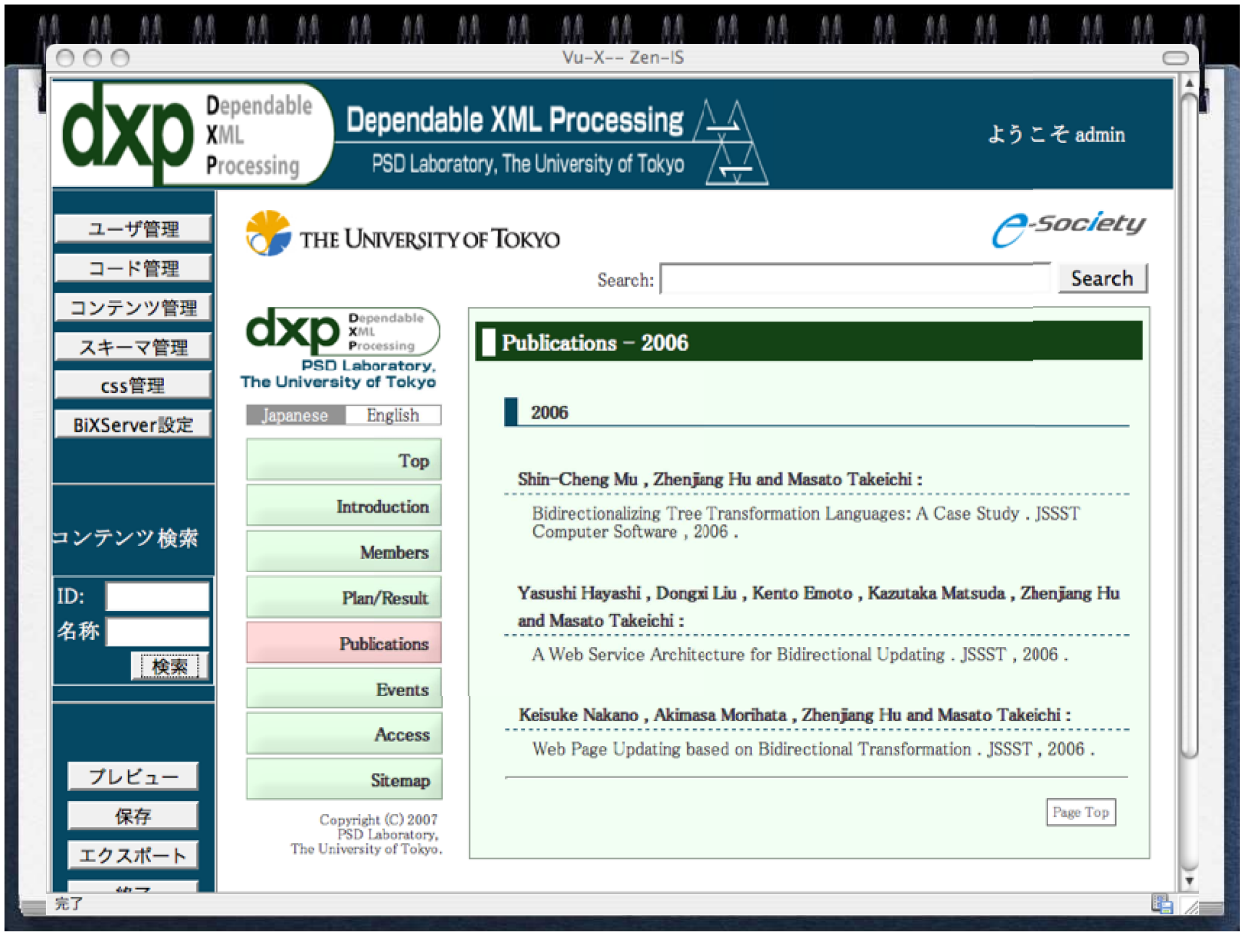

http://www.psdlab.org/vux/

Bidirectional Languages

- Inv: an injective language for revertible computation

  [MPC'04, APLAS'04]

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- Bi-Haskell: a general bidirectional functional language

Write forward transformation and get backward transformation for free!

Bidirectionalization

- Bidirectionalization of *XSLT* [JSSST-CS:06]

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- Bidirectional Interpretation of *XQuery* [ACM PEPM'07]

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Bidirectionalization

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- Bidirectional Interpretation of *XQuery* [ACM PEPM'07]
- Bidirectional Interpretation of *ATL* [ACM/IEEE ASE'07]
- Bidirectionalization of a small general functional language [ACM ICFP'07]

Outline

BiX

- A Combinator-based language

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  - Primitive bidirectional transformations for tree manipulation, which is extensible.

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  - Combinators for composing smaller bidirectional transformations

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  - Combinators for composing smaller bidirectional transformations

We only need to prepare a pair of transformations for each primitive bidirectional transformation, other backward transformations are obtained for free.

Primitive Bi-Transformations

Primitive bidirectional transformations for tree manipulation:

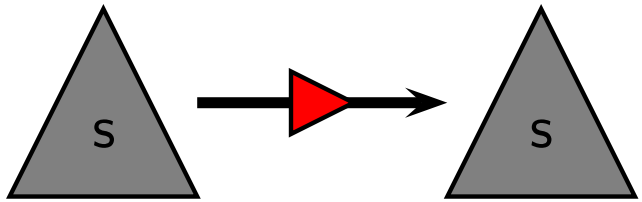
- for tree destruction, e.g.,
  - *xid*
  - *xleftchild*
- for tree construction, e.g.,
  - *xconst t*
  - *xdup*
  - *xnewroot n*

xid

- Identity Transformation

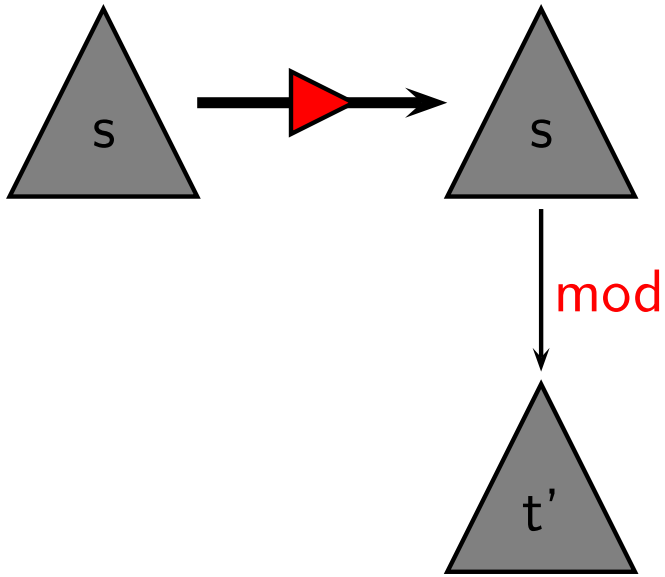
xid

- Identity Transformation



xid

- Identity Transformation



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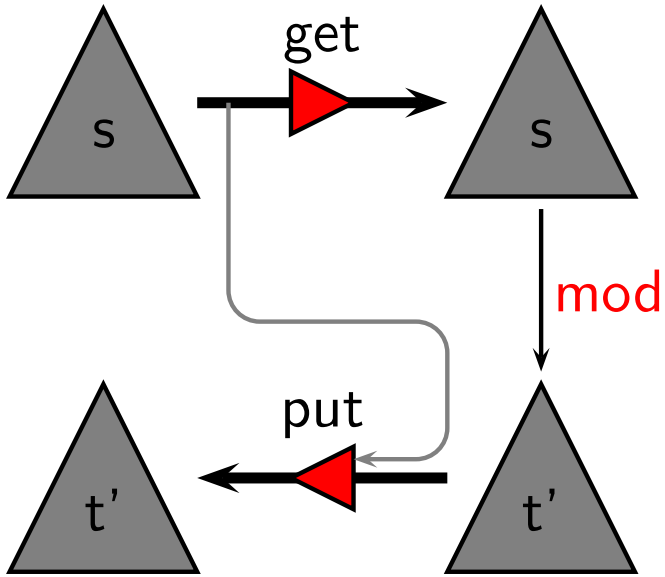

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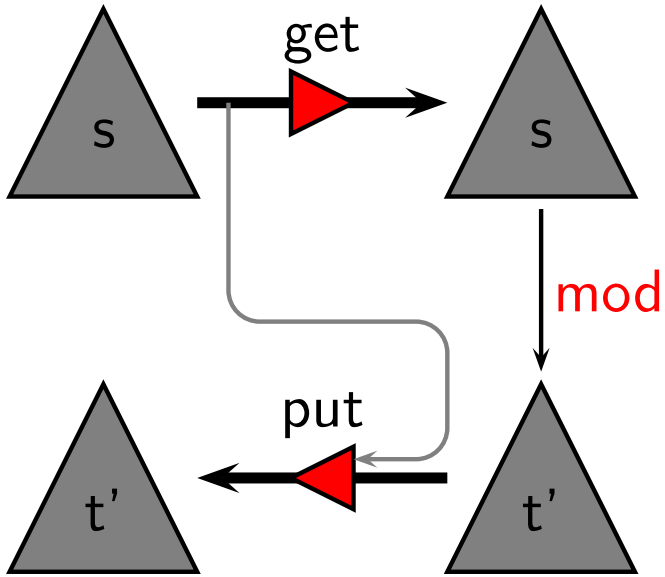

$$\begin{aligned} \text{get } s &= s \\ \text{put } t'\ s &= t' \end{aligned}$$

xleftchild

- Select the leftmost child of the root

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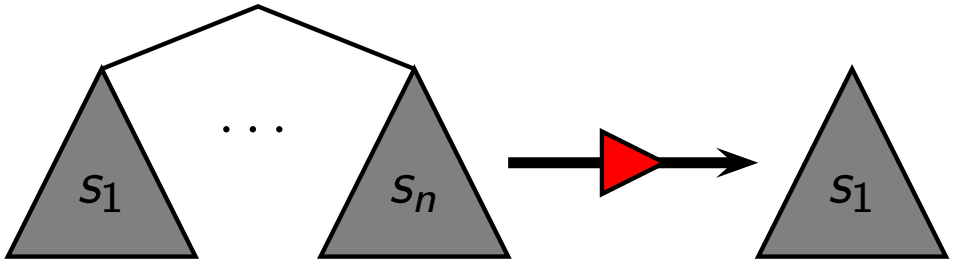

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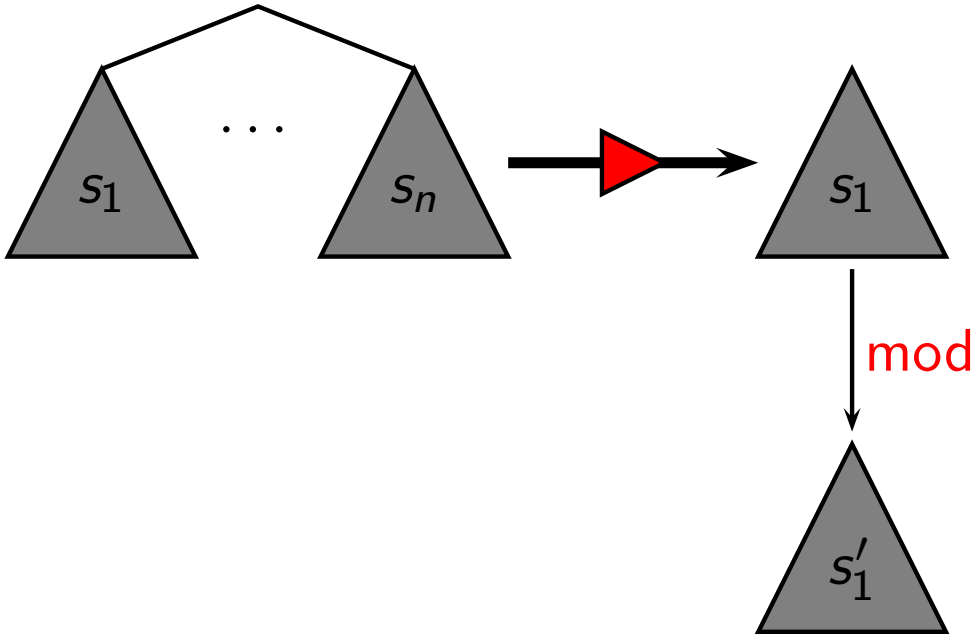

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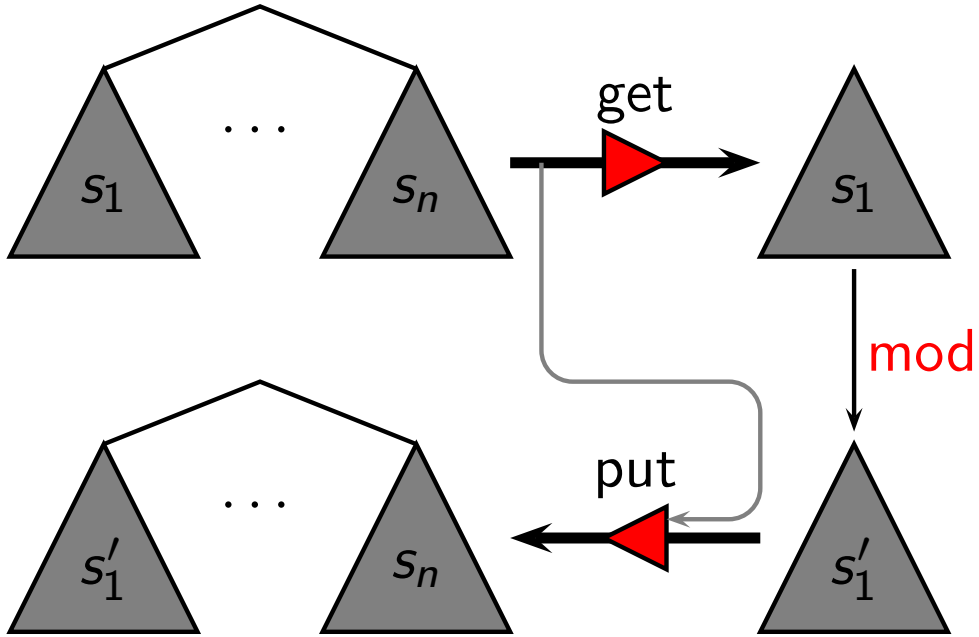

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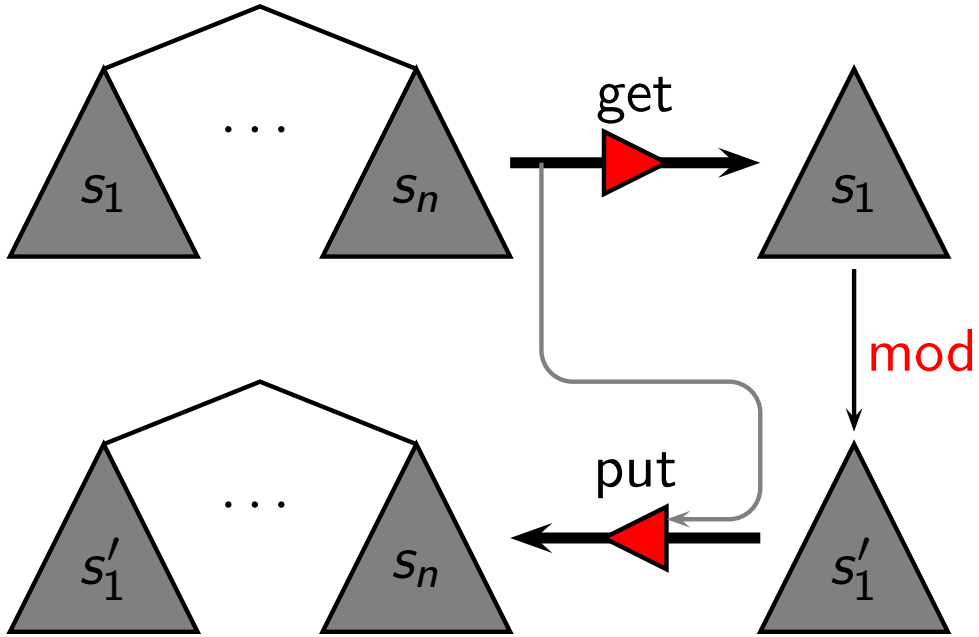

$$\text{get}\ (\mathit{Node}\ n\ [s_1, \ldots, s_n]) = s_1$$
$$\text{put}\ s'_1\ (\mathit{Node}\ n\ [s_1, \ldots, s_n]) = \mathit{Node}\ n\ [s'_1, \ldots, s_n]$$

xconst t

- Constant Transformation:

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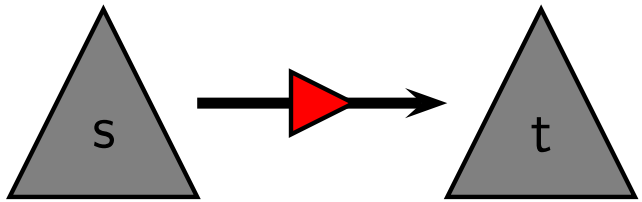

xconst *t*

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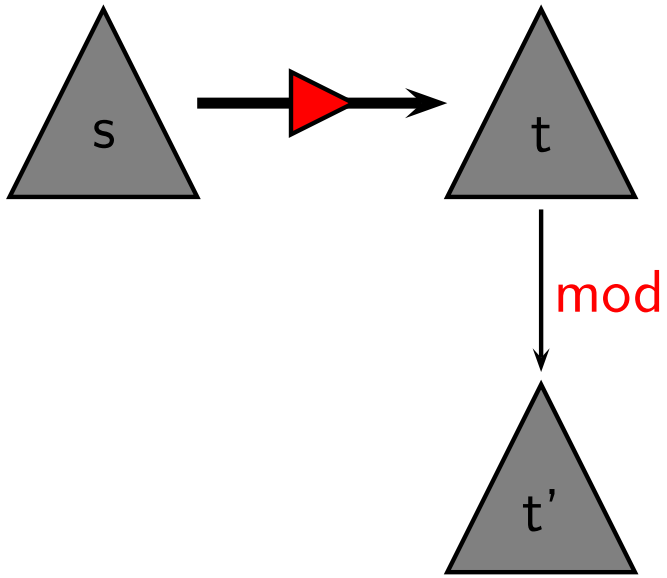
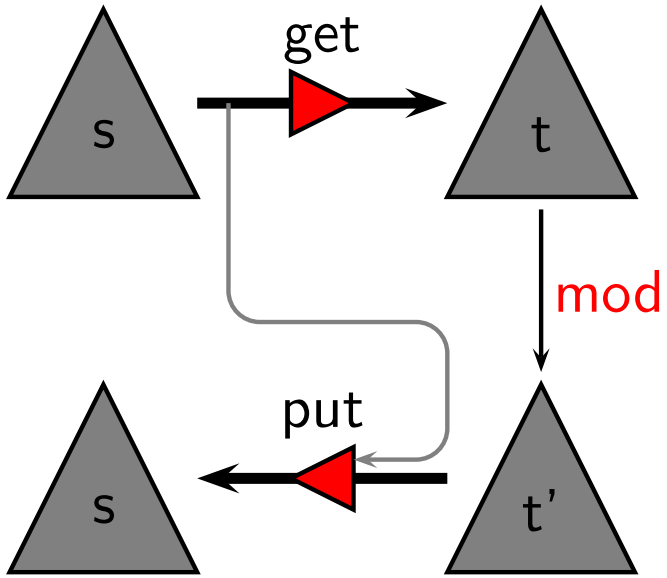


xconst t

- Constant Transformation: disallow any modification on the target.



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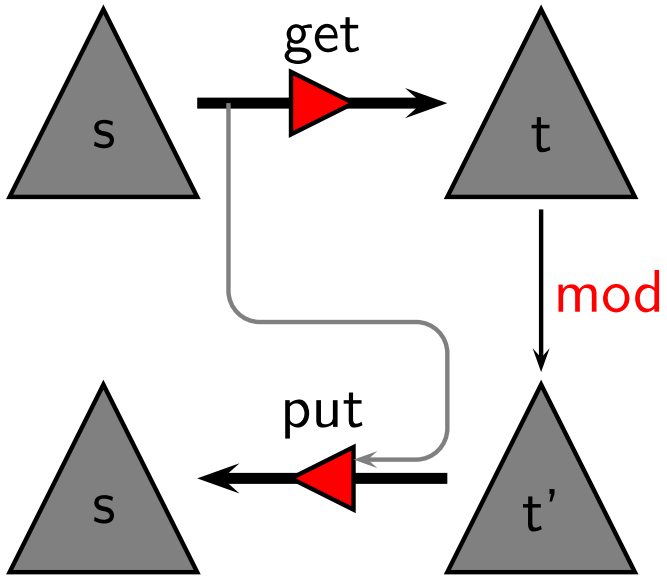

$$\begin{aligned} \text{get } s &= t \\ \text{put } t' \ s &= s \end{aligned}$$

xdup

- Replicate data:

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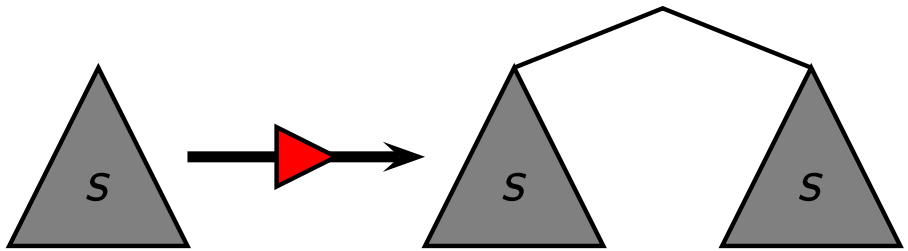

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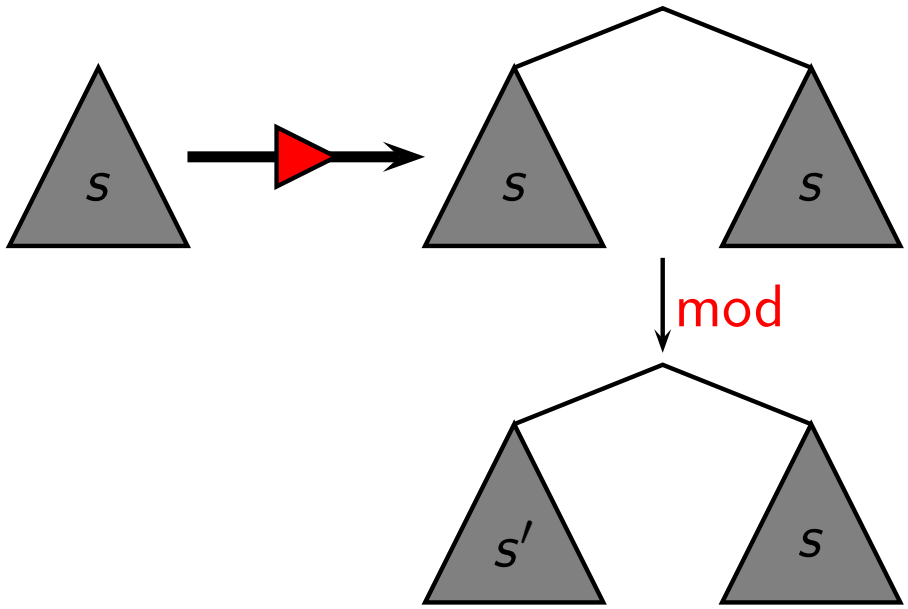

xdup

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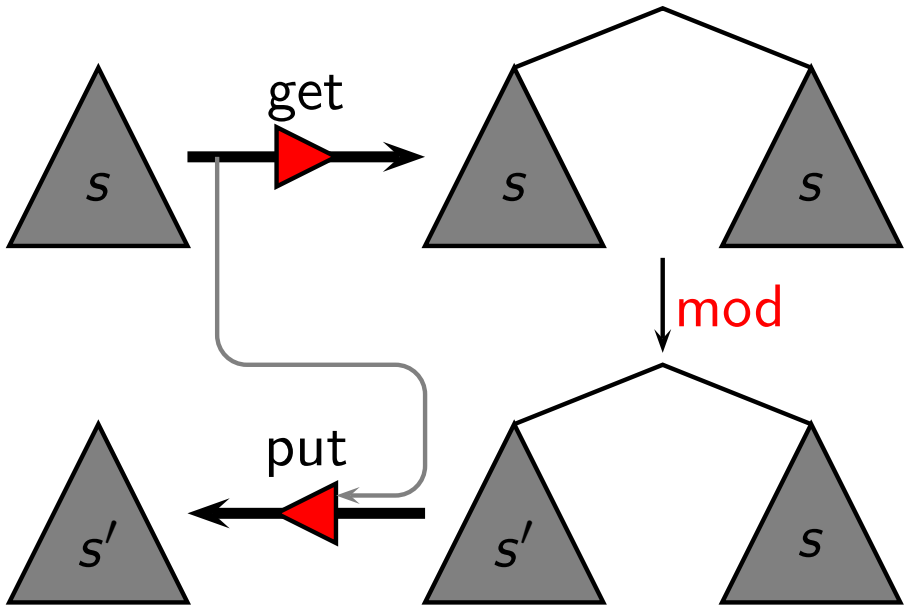
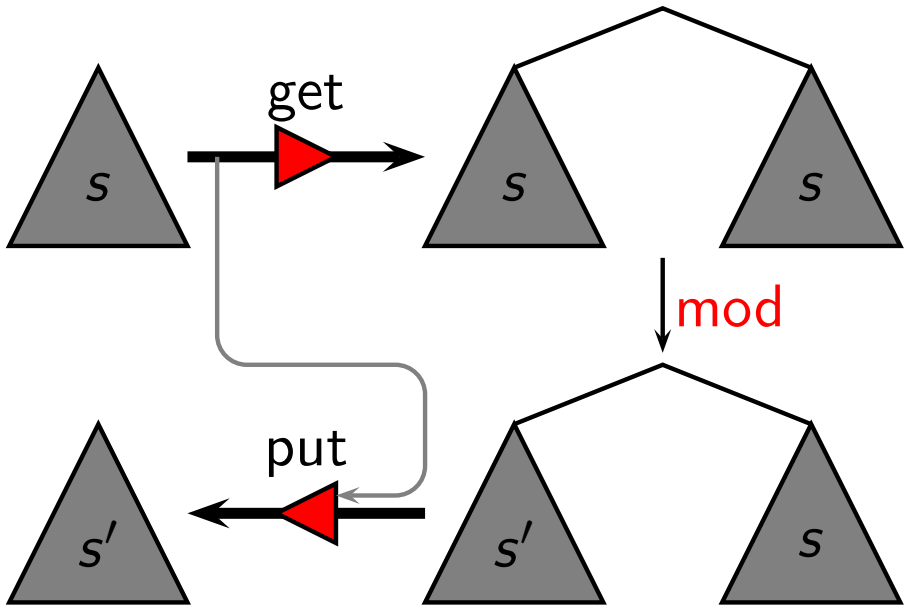


xdup

- Replicate data: allow data dependency in the target



$$\begin{aligned} \text{get } s &= \mathit{Node}\ \_\ [s, s] \\ \text{put } (\mathit{Node}\ \_\ [s_1, s_2])\ s &= \textbf{if } s = s_1 \textbf{ then } s_2 \textbf{ else } s_2 \end{aligned}$$

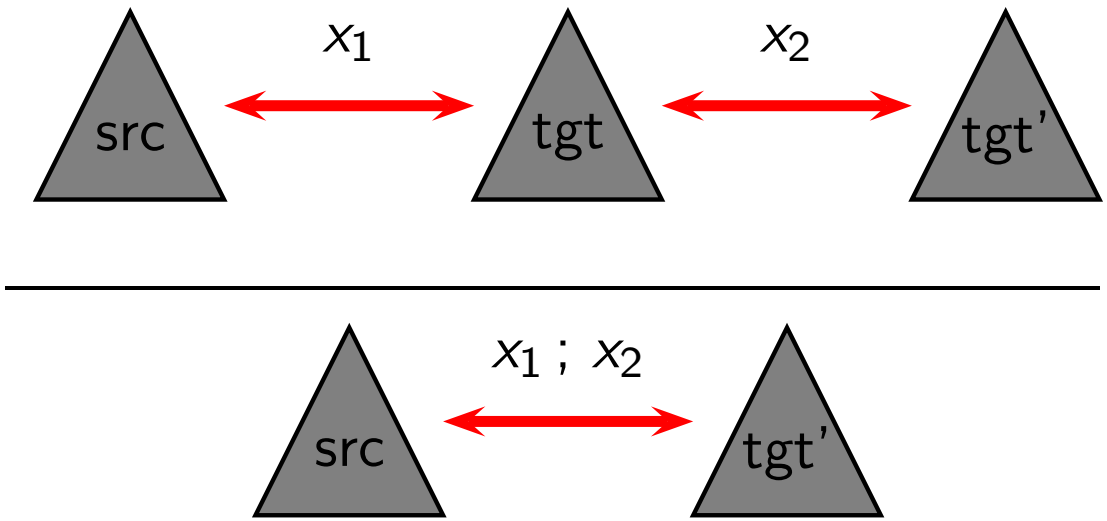
Assume we have only one modification.

Combinators

Used to construct bigger bidirectional transformations by composing smaller bidirectional transformations.

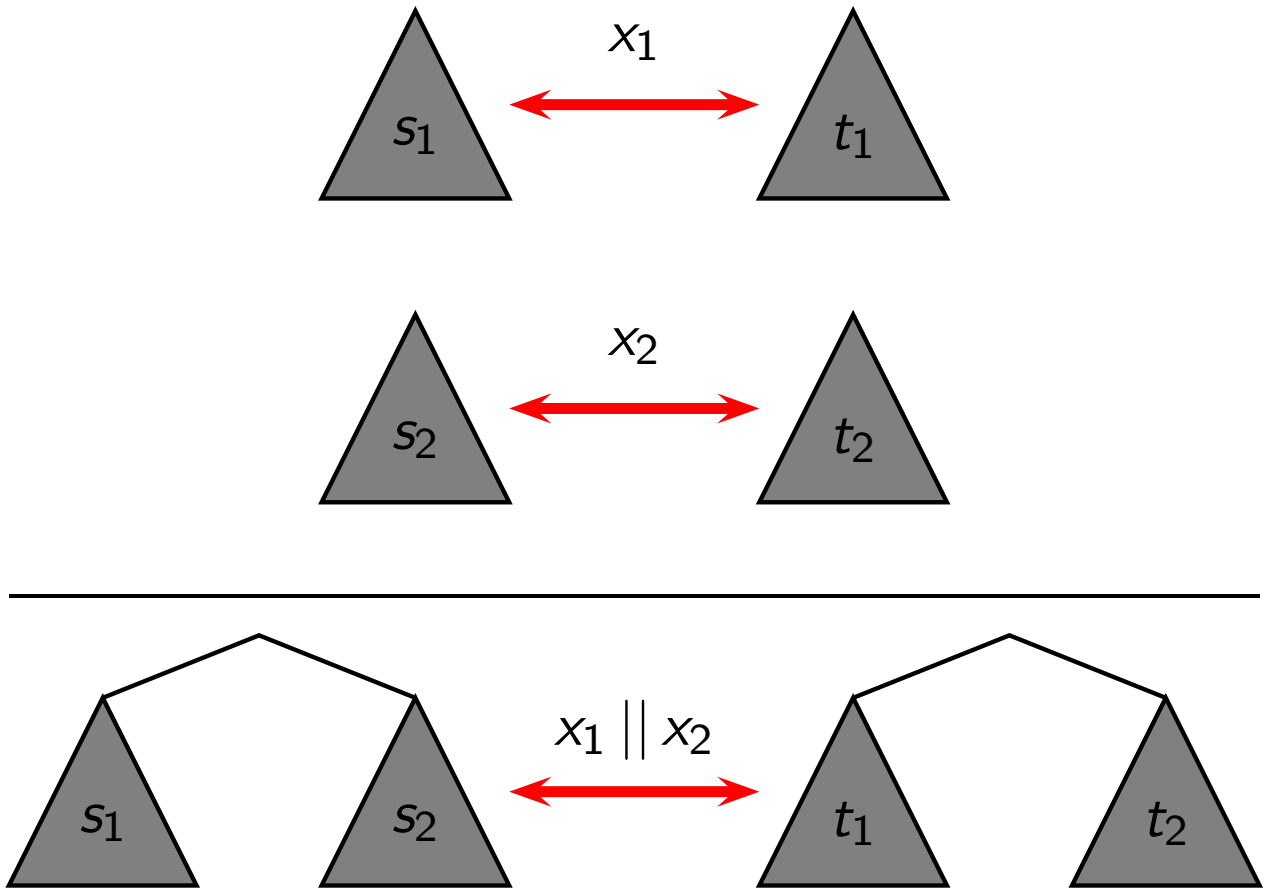
- Sequential composition: $x_1 \; ; \; x_2$
- Parallel composition: $x_1 \; || \; x_2$
- Conditional: xif $p \; x_1 \; x_2$
- Map to each: xmap x

Sequential Composition

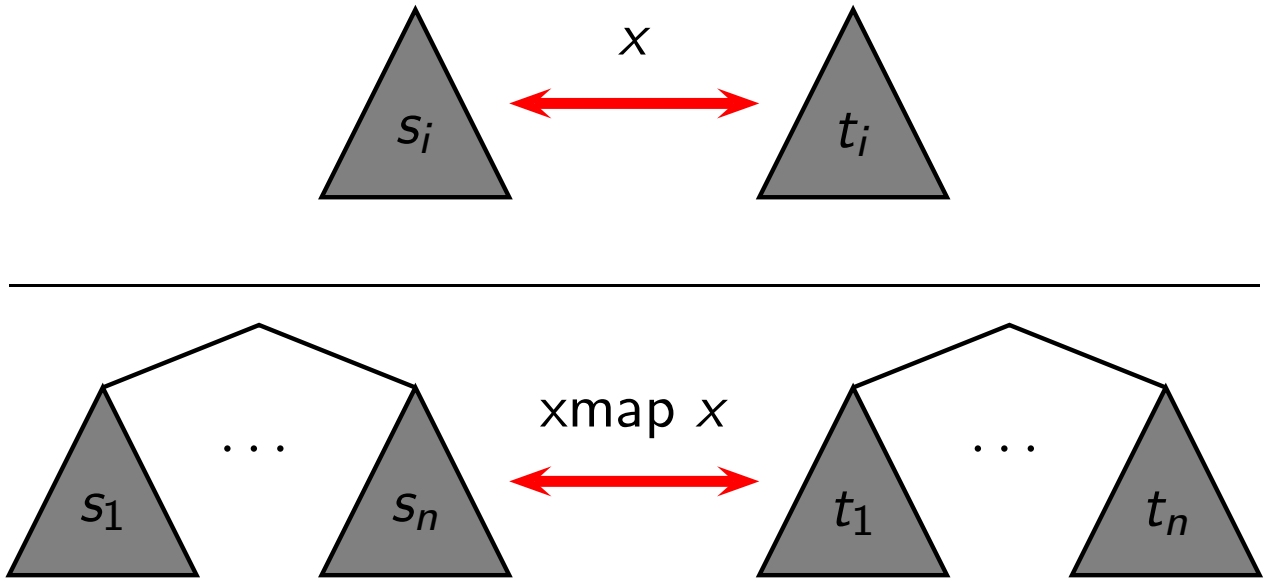


$$\begin{aligned} \text{get}_{(x_1\,;\,x_2)}\ s &= \text{get}_{x_2}(\text{get}_{x_1}\ s) \\ \text{put}_{(x_1\,;\,x_2)}\ t'\ s &= \text{put}_{x_1}\ (\text{put}_{x_2}\ t'\ (\text{get}_{x_1}\ s))\ s \end{aligned}$$

Parallel Composition

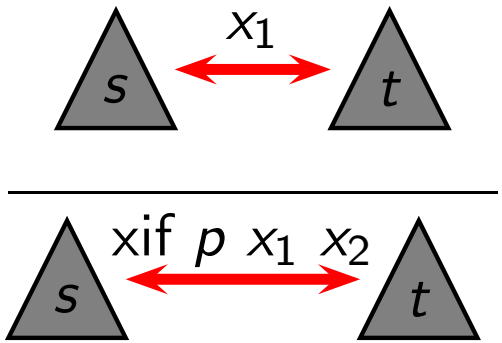


Map-to-each

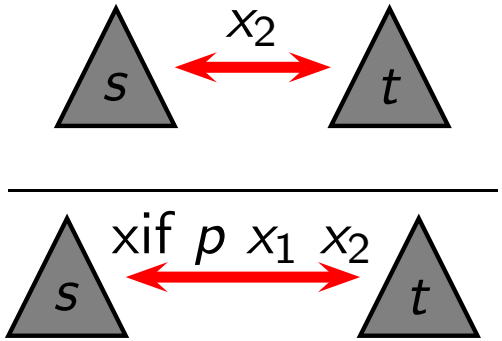


Conditional

If $p\ s$ holds, then



otherwise,



Summary of the Core BiX

$$
\begin{array}{lll}
X & ::= & \mathit{xid} \mid \mathit{xconst}\ S \mid \mathit{xchild} \mid \mathit{xsetcnt}\ X \mid \ldots \\
 & & \mid X_1; X_2 \mid X_1 || X_2 \mid \mathit{xmap}\ X \mid \mathit{xif}\ P\ X_1\ X_2 \\
 & & \mid \mathit{xlet}\ \mathit{Var}\ X \mid \mathit{xvar}\ \mathit{Var} \\
 & & \mid \mathit{xfunapp}\ \mathit{fname}\ [X_1, ..., X_n] \\
 & & \\
P & ::= & \mathit{xwithtag}\ \mathit{str} \mid \mathit{xistext} \mid \mathit{xiselement} \mid X \\
 & & \\
\mathit{Def} & ::= & \mathit{fun}\ \mathit{fname}(\mathit{Var}_1, ..., \mathit{Var}_n) = X
\end{array}
$$

A Programming Example: toc

- Source Data:

```
<book>
  <title>Data on the Web</title>
  <author>Serge</author><author>Peter</author>
  <author>Dan Suciu</author>
  <section id="intro" difficulty="easy">
    <title>Introduction</title><p>Text ... </p>
    <section>
      <title>Audience</title><p>Text ... </p>
    </section>
  </section>
  <section id="syntaxnew" difficulty="medium">
    <title>A Syntax For Data</title><p>Text ... </p>
  </section>
</book>
```

A Programming Example: toc

- Target data we want to have is a table-of-contents.

```
<toc>
  <section id="intro">
    <title>Introduction</title>
    <section><title>Audience</title></section>
  </section>
  <section id="syntaxnew">
    <title>A Syntax For Data</title>
  </section>
</toc>
```

A Programming Example: toc

- The transformation in BiX to produce the table of contents from a book:

```
fun toc($book-or-section) =
  xvar $book-or-section; xchild;
  xmap (xif (xwithtag ‘‘section’’) X0 (xconst ()))
where
  X0 = xlet $section
            (xconst <section>[]; xsetcnt (X1||X2))
  X1 = xvar $section; xchild;
       xmap (xif (xwithtag ‘‘title’’) xid (xconst ()))
  X2 = xfunapp toc [xvar $section]
```

We can obtain BiX from XQuery

- Making the table-of-contents from a book.

```
declare function local:toc($book-or-section)
{
  for $section in $book-or-section/section
  return
    <section>
      {$section/@id, $section/title,
       local:toc($section)}
    </section>
};
<toc>
   { for $s in doc("book.xml")/book
     return local:toc($s)}
</toc>
```

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software engineering +
programming languages +
transformational programming $\Rightarrow$ a new paradigm