Resourceful Lenses for Ordered Data

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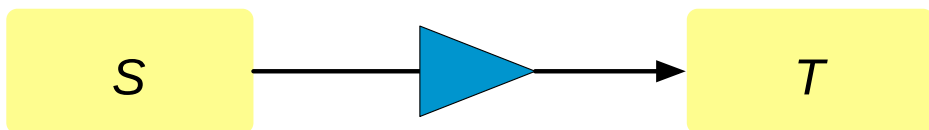
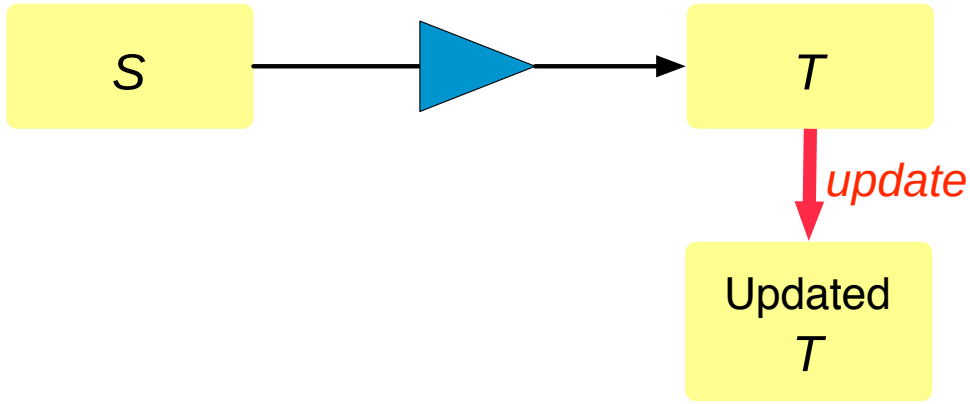
Bidirectional Mappings

- Most programs work in one direction—from source to target



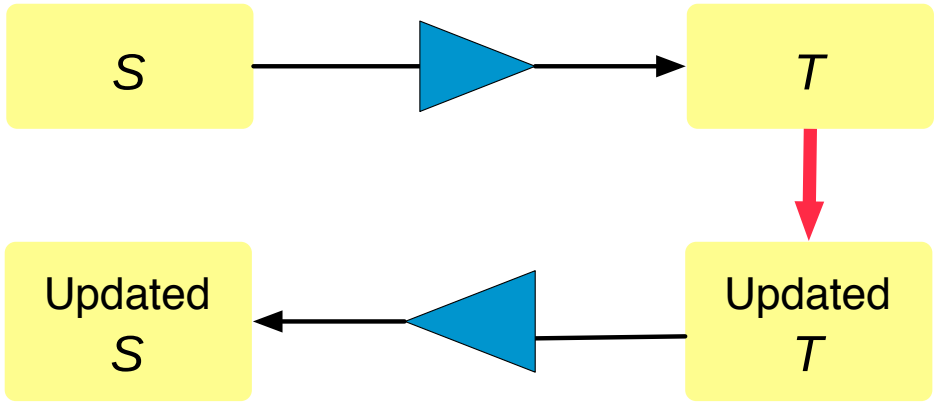
Bidirectional Mappings

- Most programs work in one direction—from source to target
- But sometimes we want to update the target



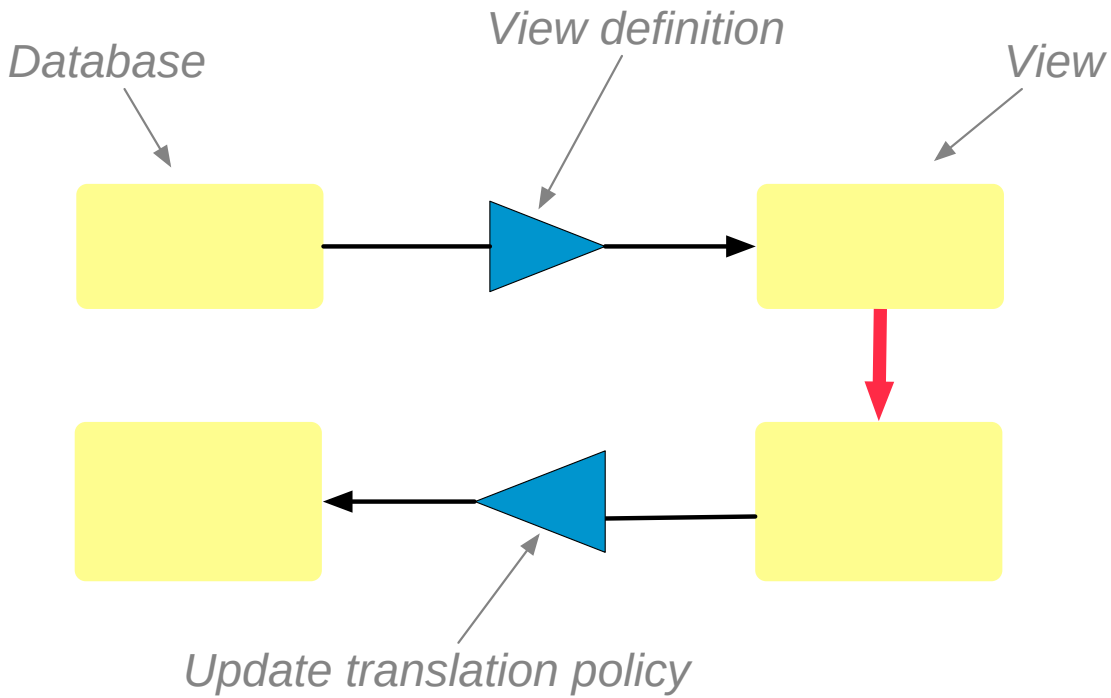
Bidirectional Mappings

- Most programs work in one direction—from source to target
- But sometimes we want to update the target
- And "translate" this update to obtain an appropriately updated source



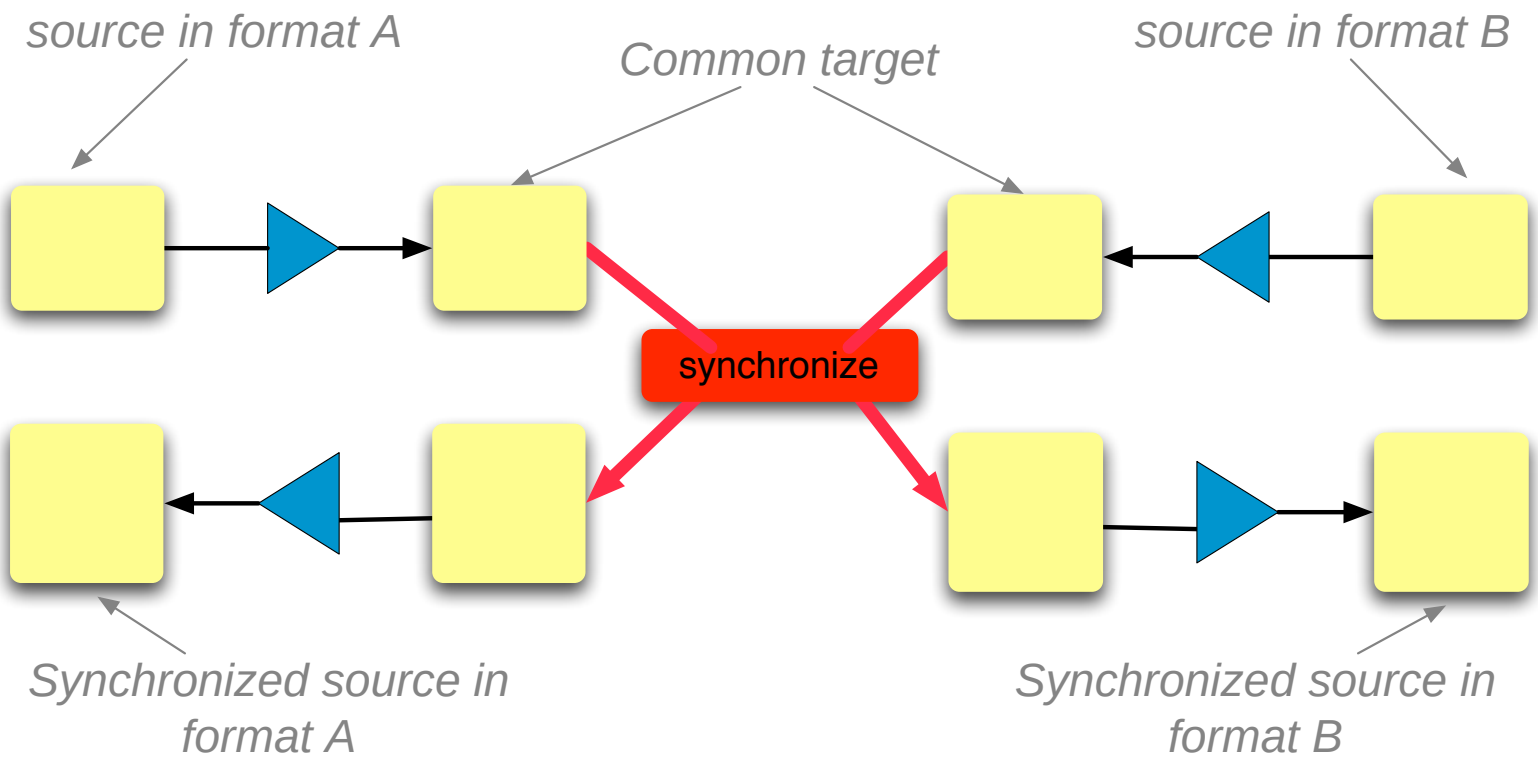
The View Update Problem

This is called the view update problem in the database literature.



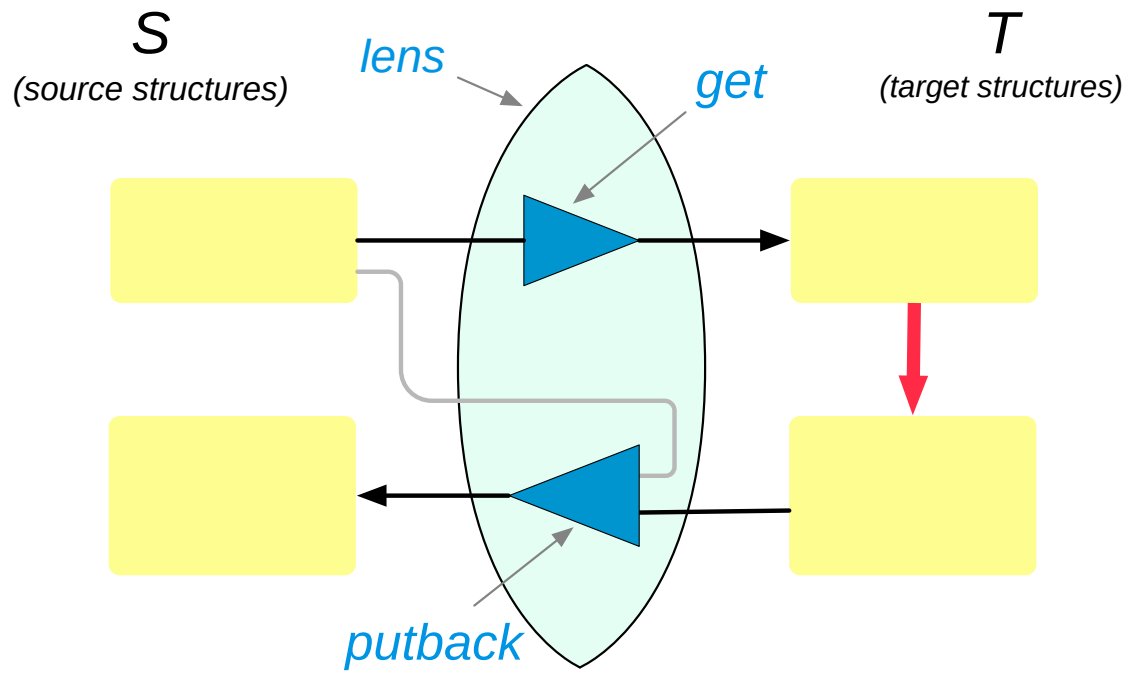
The View Update Problem In Practice

...but also comes up in other contexts, such as data synchronization.



Linguistic Approach

Lenses: bidirectional programs where each expression denotes both functions.



$$get : S \to T$$
$$put : T \times S \to S$$

Address Books (Get)

Source string (vCard dialect used in `Address Book.app`):

```
BEGIN:VCARD
VERSION:3.0
N:Pierce;Benjamin C.;;;
FN:Benjamin C. Pierce
TEL;type=HOME;type=pref:215 732-4684
TEL;type=CELL:215 266-9001
TEL;type=WORK:215 898-6222
X-ABUID:87B85E7E-AB0F-4819-8647-0BD532019144\:ABPerson
END:VCARD
```

Target string (simple ASCII format):

```
Pierce, Benjamin C., 215 732-4684 (h), \
215 266-9001 (c), 215 898-6222 (w)
```

SwissProt (Get)

Source string (SwissProt ASCII):

```
OS   Solanum melongena (Eggplant) (Aubergine).
OG   Plastid; Apicoplast.
OC   Mammalia; Eutheria.
OX   NCBI_TaxID=9606;
OH   NCBI_TaxID=9481; Callithrix.
OH   NCBI_TaxID=9536; Cercopithecus hamlyni (Owl-faced
OH   monkey) (Hamlyn's monkey).
```

SwissProt (Get)

Target string (SwissProt XML):

```
<organism key="1">
 <name type="scientific">Solanum melongena</name>
 <name type="common">Eggplant</name>
 <name type="synonym">Aubergine</name>
 <dbReference type="NCBI Taxonomy" key="1" id="9606"/>
 <lineage>
  <taxon>Mammalia</taxon>
  <taxon>Eutheria</taxon>
 </lineage>
</organism>
...
<geneLocation type="apicoplast"/>
```

BibTeX (Get)

Source string:

```
CIS 700 Project - Fall 2005.
@incollection{FJ-afp,
author = {J. Nathan Foster and Dimitrios Vytiniotis},
title = {A Theory of {F}eatherweight {J}ava
         in {I}sabelle/{H}{O}{L}},
booktitle = {The Archive of Formal Proofs},
editor = {Gerwin Klein
          and Tobias Nipkow
          and Lawrence Paulson},
publisher = {http://afp.sf.net},
year = 2006,
month = April,
url = {http://afp.sf.net/entries/FeatherweightJava.shtml},
}
```

BibTeX (Get)

Target string:

```
TY  - CHAP
ID  - FJ-afp
AU  - Foster, J. Nathan
AU  - Vytiniotis, Dimitrios
ED  - Klein, Gerwin
ED  - Nipkow, Tobias
ED  - Paulson, Lawrence
T1  - A theory of Featherweight Java in Isabelle/HOL
T2  - The Archive of Formal Proofs
PB  - http://afp.sf.net
PY  - 2006/04//
UR  - http://afp.sf.net/entries/FeatherweightJava.shtml
ER  -
```

BibTeX (Lens Definition)

Primitives + regular operators, embedded in λ-calculus:

```
let do_types =
    do_type "article" "JOUR"
  | do_type "inproceedings" "CONF"
  | do_type "misc" "UNPB"
  | do_type "incollection" "CHAP"
  | do_type "mastersthesis" "THES"
  | do_type "manual" "COMP"
  | do_type "phdthesis" "THES"
let entry =
  delete_non_entry .
  do_types . newline .
  do_key . newline .
  do_fields . (ws_nl . "}") <-> "ER  -\n\n"
let bibtex2ris = entry* . delete_non_entry
```

BibTeX (Put Direction)

Putting new target:

```
TY  - CHAP
ID  - FJ-afp
...
T1  - A theory of Featherweight...
ER  -

TY  - JOUR
ID  - Focal-toplas
...
T1  - Combinators for bidirectional...
ER  -
```

into original source...

BibTeX (Put Direction)

...yields new source:

```
CIS 700 Project - Fall 2005.
@incollection{FJ-afp,
  ... title = {A theory of {F}eatherweight...}, ...
}

@article{Focal-toplas,
   ... title = {Combinators for bidirectional...}, ...
}
```

Kleene-* and Alignment

Unfortunately, there is a serious problem lurking here.

The *put* component of $l*$ splits its T and S inputs into sequences of elements

$$t = t_1 \;.\; t_2 \;.\; t_3 \ldots$$
$$s = s_1 \;.\; s_2 \;.\; s_3 \ldots$$

then invokes the *put* of l on t_1 and s_1, on t_2 and s_2, etc., and then forms a list of the results.

This does not always give us what we want!

A Bad Put

Putting target:

```
TY  - JOUR
ID  - Focal-toplas
...
T1  - Combinators for bidirectional...
ER  -

TY  - CHAP
ID  - FJ-afp
...
T1  - A theory of Featherweight...
ER  -
```

into original source...

A Bad Put

...yields mangled source:

```
CIS 700 Project - Fall 2005.
@article{Focal-toplas,
  ... title = {Combinators for bidirectional...},...
}

@incollection{FJ-afp,
 ... title = {A theory of {F}eatherweight...},...
}
```

This is Serious

This problem arises whenever lenses are used to deal with list-structured data—sequences where ordering is important and where updates can add, delete, and rearrange elements.

Specifically, it arises when we want to *both* reorder "chunks" of data in the target *and* (in the *get* direction) project away part of each chunk (e.g., the comments associated with each entry).

Our experience writing lenses for a variety of real-world formats suggests that such situations arise frequently in practice.

None of the bidirectional languages proposed in the literature gets this right.

Resourceful Lenses

The Way Forward

We want the *put* function, when it reaches a sequence of reorderable "chunks," to align chunks from the source and target using a criterion other than their position in the sequence.

- In the example, we want to match up lines that have identical BibTeX keys.

That is, we need to introduce a (weak) notion of provenance into our syntax (and semantics!).

Provenance and Lenses

Let's restate what is wrong with the BibTeX example using provenance: entries in the target may be *put* with entries in the source that are not in their provenance set—e.g.:

```
TY  - JOUR
ID  - Focal-toplas
...
T1  - Combinators for bidirectional...
ER  -
```

and

```
CIS 700 Project - Fall 2005.
@incollection{FJ-afp,
 ... title = {A theory of {F}eatherweight...},...
}
```

R-lenses

Resourceful lenses (or *R-lenses*) include annotations for tracking correspondences between pieces of the source and target structures.

Programs identify:

- re-orderable chunks in source and target;
- a key for each chunk.

The *put* function uses a dictionary of all the source chunks, indexed by key, as a resource for processing target chunks.

BibTeX (Revised Lens Definition)

```
let do_key =
  ins (tag "ID") .
  key [^@{}",\n ]+ .
  ("," . ws . "\n") <-> ""

let chunk =
  delete_non_entry .
  do_type . newline .
  do_key . newline .
  do_fields . (ws_nl . "}") <-> "ER  -\n\n"
let bibtex2ris = (<chunk>)* . delete_non_entry
```

Extensions and Open Questions

More examples:

- Require more powerful primitives swapping, sorting, permuting, etc.

Richer kinds of "keys":

- In the current implementation, keys are strings, assembled by concatenating the keys of sub-lenses.

Extend to trees:

- What are good notions of "chunk" and "key" for trees?
- How are they specified?

Can better notions of provenance to put to use:

- In lenses?
- In data synchronizers?

Thank You!

Main collaborators on this work: Aaron Bohannon, Benjamin C. Pierce, Alexandre Pilkiewicz, Alan Schmitt

Other Harmony contributors: Ravi Chugh, Malo Denielou, Michael Greenwald, Owen Gunden, Martin Hofmann, Sanjeev Khanna, Keshav Kunal, Stéphane Lescuyer, Jon Moore, Jeff Vaughan, Zhe Yang

Resources: Papers, slides, (open) source code, and online demos:

http://www.seas.upenn.edu/~harmony/