Expanding the Power of Lens Synthesis

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Learning DSLs is Hard

\[ l : R \leftrightarrow S \]

\[ \text{disconnect}(R,...) \]

\[ \text{swap \ (concat \ (swap \ ...)} \]
Synthesis as a Solution

$R, S$

examples

$l : R \Leftrightarrow S$
Synthesis as a Solution

$R, S$

eamples

$l : R \Leftrightarrow S$
Synthesis as a Solution

$R, S$

examples

$l : R \Leftrightarrow S$
Synthesizing Bidirectional Programs


- Integrated into Boomerang [Bohannon et al. 2008]
A Framework for Lens Synthesis
We can synthesize...

- Bijective Lenses
- Quotient Lenses
- Asymmetric Lenses
- Symmetric Lenses
Bijective Lens Synthesis

Annotated Regular Expression

Whole

Converter

Kernel

Synthesized Core

Kernel

Converter

Whole
Bijective Lenses
Bijective Lenses

Sibelius, 1965

$l$
Bijective Lenses

Sibelius, 1965

\( l \)

N: Sibelius
B: 1965
Bijective Lenses

Sibelius, 1965

\( l \)

N: Sibelius
B: 1965
Bijective Lenses

Sibelius, 1965

l

N: Sibelius
B: 1965
Bijective Lenses

Sibelius, 1965

N: Sibelius
B: 1865
Bijective Lenses

\[ l \]

Sibelius, 1865

N: Sibelius
B: 1865
Bijective Synthesis

$R, S$

examples

$l : R \Leftrightarrow S$
Quotient Lens Synthesis
Quotient Lenses

\[ l \]
Quotient Lenses

Sibelius, 1865
Quotient Lenses
Quotient Lenses

Sibelius, 1865

N: Sibelius
B: 1865
Quotient Lenses

Sibelius, 1865

l

N: Sibelius
B: 1865
Quotient Lenses

Sibelius, 1865

l

N: Sibelius
B: 1865
Quotient Lenses

Permissive in input
Restrictive in output

Sibelius, 1865

\( l \)

N: Sibelius
B: 1865
Quotient Lenses

Sibelius, 1865

Sibelius, 1865

Sibelius, 1865

N: Sibelius
B: 1865
Quotient Lenses

Sibelius, 1865

Sibelius, 1865

Sibelius, 1865

l

N: Sibelius
B: 1865
Quotient Lenses

Sibelius, 1865

N: Sibelius
B: 1865
Quotient Lens Synthesis
Quotient Lens Synthesis
QRE

Noncanonical Format -> Sibelius, 1865 -> Canonical Format

Canonizer
QRE

Noncanonical Format → Sibelius, 1865 → Canonical Format
QRE

Noncanonical Format  →  Canonizer  ←  Canonical Format

Sibelius, 1865
QRE

Noncanonical Format → Canonizer →Canonical Format

Sibelius, 1865
QRE

Sibelius, 1865

Noncanonical Format

Canonizer

Canonical Format
QRE

Sibelius, 1865

Sibelius, 1865

Sibelius, 1865

Sibelius, 1865
Name: "Sibelius, 1865"
. Date: "Sibelius, 1865"
Sibelius, 1865

Name . ",".
  . (squash(WSP) -> " ")
  . Date
QRE

Name . "," . (squash(WSP) -> " " "") . Date
QRE

Name: "", 
 . (squash(WSP) -> " ")
 . Date
QRE

Name: "" (squash(WSP) \rightarrow """)
Date
QRE

Name . "", "
. WSP
. Date

Sibelius, 1865

Sibelius, 1865

Sibelius, 1865

Name . "", "
. " "
. Date

Name . "", "
. (squash(WSP) -> " ")
. Date
Quotient Lens Synthesis

Uncanonized Format \rightarrow Canonizer \rightarrow Canonized Format \rightarrow Canonizer \rightarrow Uncanonized Format

Bijective Core
Quotient Lens Synthesis

Uncanonized Format ----> Canonizer ----> Canonized Format ----> Bijective Core ----> Canonized Format ----> Canonizer ----> Uncanonized Format
Quotient Lens Synthesis

Sibelius, 1865

Uncanonized Format → Canonizer → Canonical Format ← Bijective Core → Canonical Format ← Canonizer → Uncanonized Format
Quotient Lens Synthesis

Sibelius, 1865
Quotient Lens Synthesis

Sibelius, 1865

Uncanonized Format → Canonizer → Canonized Format

Canonizer → Bijective Core → Canonizer

Canonizer → Canonized Format → Canonizer

Uncanonized Format
Quotient Lens Synthesis

Sibelius, 1865

Uncanonized Format → Canonizer → Canonized Format → Bijective Core → Canonized Format → Canonizer → Uncanonized Format
Quotient Lens Synthesis

N: Sibelius
B: 1865
Quotient Lens Synthesis

N: Sibelius
B: 1865

Uncanonized Format → Canonizer → Canonized Format → Bijective Core → Canonized Format → Canonizer → Uncanonized Format
Quotient Lens Synthesis

N: Sibelius
B: 1865
Quotient Lens Synthesis

N: Sibelius
B: 1865
Quotient Lens Synthesis

N: Sibelius
B: 1865

Uncanonized Format → Canonizer → Canonized Format

Bijective Core

Canonizer → Canonized Format → Canonizer

Uncanonized Format
Quotient Lens Synthesis

Sibelius, 1865

Uncanonized Format → Canonizer → Canonized Format → Bijective Core → Canonized Format → Canonizer → Uncanonized Format
Quotient Lens Synthesis

Sibelius, 1865

Uncanonized Format → Canonizer → Canonized Format ← Bijective Core → Canonized Format ← Canonizer → Uncanonized Format
Asymmetric Lens Synthesis

Full Format → Projector → Projected Format ← Bijective Core ← RE

PRE
Asymmetric Lenses
Asymmetric Lenses

Sibelius, 1865 \( l \) N: Sibelius
Asymmetric Lenses

Sibelius, 1865

l

N: Sibelius
Asymmetric Lenses

Sibelius, 1865

N: Sibelus
Asymmetric Lenses

Sibelus, 1865

N: Sibelus
Asymmetric Lenses

Sibelus, 1865

l

N: Sibelus
Asymmetric Lenses

Sibelus, 1965

N: Sibelus
Asymmetric Lenses

Sibelus, 1965

N: Sibelus
Asymmetric Lenses

Sibelus, 1965

l

N: Sibelus
Asymmetric Lenses

Sibelius, 1965

N: Sibelus
Asymmetric Lenses

Sibelius, 1965

N: Sibelius
Asymmetric Lenses

Shared Data

Sibelius, 1965

N: Sibelius
Asymmetric Lenses

Shared Data

Sibelius, 1965

l

N: Sibelius

Distinct Data
Asymmetric Lenses

Shared Data

Sibelius, 1965

Distinct Data

Shared Data

N: Sibelius
Asymmetric Lens Synthesis
PRE

Full Format

Projector

Projected Format
Sibelius, 1965

Full Format

Projector

Projected Format
PRE

Full Format

Projector

Projected Format

Sibelius
PRE

Sibelius, 1965

Full Format

Projector

Projected Format
PRE

Sibelius, 1965

Full Format

Projector

Projected Format
PRE

Full Format

Projector

Sibelus,

Projected Format
PRE

Full Format

Sibelus,

Projector

Projected Format
PRE

Full Format

Sibelius, 1965

Projected Format

Sibelius, 1965

Projector
PRE

Sibelus, 1965

Full Format

Projector

Projected Format
PRE

Sibelus, 1965

Full Format

Projector

Projected Format
PRE

Sibelius, 1965

Name . "", "
. skip(Date)
PRE

Sibelius, 1965

Name "", ""
  . skip(Date)
PRE

Sibelius, 1965

Name . ", " 
. skip(Date)
Name "_,_"
_. skip(Date)
PRE

Name . "", "
. Date

Sibelius, 1965

Name . "", "
. skip(Date)

Sibelius,
Asymmetric Lens Synthesis
Sibelius, 1865

Full Format  Projector  Projected Format  Bijective Core  RE

PRE
Sibelius,

PRE

Full Format

Projector

Projected Format

Bijective Core

RE
Sibelius,

**PRE**

- Full Format
- Projector
- Projected Format

**RE**

- Bijective Core

101
N: Sibelius

PRE

Full Format

Projector

Projected Format

Bijective Core

RE

102
PRE

Full Format

Projector

Projected Format

Bijective Core

RE

N: Sibelius
N: Sibelus
N: Sibelus

PRE

Full Format

Projector

Projected Format

Bijective Core

RE
Sibelius, 1985

PRE

Full Format

Projector

Projected Format

Bijective Core

RE

108
Sibelus, 1985

PRE

Full Format

Projector

Projected Format

Bijective Core

RE

109
Sibelus, 1985

PRE

Full Format

Projector

Projected Format

Bijective Core

RE

110
Symmetric Lens Synthesis

Full Format → Projector → Projected Format → Bijective Core → Projected Format → Projector → Full Format
Symmetric Lenses

\[ l \]
Asymmetric Lenses

Sibelus, 1865

l

N: Jean Sibelus
Asymmetric Lenses

Sibelius, 1865

l

N: Jean Sibelius
Asymmetric Lenses

Sibelius, 1865

l

N: Jean Sibelius
Asymmetric Lenses

Sibelius, 1865

l

N: Jean Sibelius
Asymmetric Lenses

Sibelius, 1865

N: John Sibelius
Asymmetric Lenses
Asymmetric Lenses

Sibelius, 1865

l

N: John Sibelius
Asymmetric Lenses

Sibelius, 1965

\[ l \]

N: John Sibelius
Asymmetric Lenses

Sibelius, \textbf{1965} \quad l \quad \text{N: John Sibelius}
Symmetric Lens Synthesis
Symmetric Lens Synthesis
Symmetric Lens Synthesis

Sibelius, 1865

PRE

Full Format

Projector

Projected Format

Bijective Core

Projected Format

Projector

PRE

Full Format

Jean Sibelius
Symmetric Lens Synthesis

Sibelius, 1865

Full Format → Projector → Projected Format → Bijective Core → Projected Format → Projector → Full Format
Symmetric Lens Synthesis

Sibelus, 1865

PRE

Full Format

Projector

Projected Format

Bijective Core

Projected Format

Projector

Full Format
Symmetric Lens Synthesis

Sibelus,

PRE

Full Format

Projector

Projected Format

Bijective Core

Projected Format

Projector

Full Format
Symmetric Lens Synthesis

Sibelus,
Symmetric Lens Synthesis

N: Sibelus

Full Format

Projector

Projected Format

Bijective Core

Projected Format

Projector

Full Format
Symmetric Lens Synthesis

N: Sibelus

Full Format  PROJECTOR  Projected Format  BIJECTIVE CORE  Projected Format  PROJECTOR  Full Format
Symmetric Lens Synthesis

Full Format → Projector → Projected Format → Bijective Core → Projected Format → Projector → Full Format

N: Jean Sibelius
Symmetric Lens Synthesis

- Full Format
- Projector
- Projected Format
- Bijective Core
- Projected Format
- Projector
- Full Format

N: Jean Sibelus
Symmetric Lens Synthesis

N: Jean Sibelius
Symmetric Lens Synthesis

N: Jean Sibelius
Symmetric Lens Synthesis

Full Format → Projector → Projected Format → Bijective Core → Projected Format → Projector → Full Format

N: Sibelius
Symmetric Lens Synthesis

N: Sibelius

PRE

Full Format

PROJECTOR

Projected Format

Bijective Core

Projected Format

PROJECTOR

Full Format
Symmetric Lens Synthesis

PRE

Full Format

Projector

Projected Format

Bijective Core

Projected Format

Projector

Full Format

Sibelius,
Symmetric Lens Synthesis

PRE

Full Format

Projector

Projected Format

Bijective Core

Projected Format

Projector

Full Format

Sibelius,
Symmetric Lens Synthesis

Sibelius, 1865
Symmetric Lens Synthesis

Sibelius, 1865

Full Format → Projector → Projected Format → Bijective Core → Projected Format → Projector → Full Format
A Framework for Lens Synthesis

Annotated Regular Expression

Whole  Converter  Kernel  Synthesized Core  Kernel  Converter  Whole
Quotient Lens Synthesis

Whole -> Converter -> Kernel (Synthesized Core) -> Kernel -> Converter -> Whole

QRE
Quotient Lens Synthesis

QRE

Uncanonized Format

Converter

Kernel

Synthesized Core

Kernel

Converter

Uncanonized Format

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Quotient Lens Synthesis
Quotient Lens Synthesis

Uncanonized Format → Canonizer → Canonized Format → Synthesized Core → Canonized Format → Canonizer → Uncanonized Format
Quotient Lens Synthesis

Uncanonized Format → Canonizer → Canonized Format

Bijection Core

Canonizer → Canonized Format → Canonizer

Uncanonized Format
Asymmetric Lens Synthesis

PRE

Full Format

Projector

Projected Format

Bijective Core

RE

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A Framework for Lens Synthesis

Annotated Regular Expression

Whole  Converter  Kernel  Synthesized Core  Kernel  Converter  Whole
Symmetric Lens Synthesis

Whole → Converter → Kernel → Synthesized Core → Kernel → Converter → Whole
Symmetric Lens Synthesis

Full Format

Converter

Kernel

Synthesized Core

Kernel

Converter

Full Format
Symmetric Lens Synthesis
Symmetric Lens Synthesis
Symmetric Lens Synthesis
A Framework for Lens Synthesis

Whole -> Converter -> Kernel -> Synthesized Core -> Kernel -> Converter -> Whole

Annotated Regular Expression

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Lens Synthesis

PRE

Full Format

Projector

Projected Format

Bijective Core

Projected Format

Projector

Full Format
Symmetric Synthesis

$R, S$ examples

$l : R \Leftrightarrow S$
Quotient Lens Synthesis
Symmetric Lens Synthesis
Summary

Framework for bidirectional program synthesis, utilizing type annotations and simpler synthesis subcomponents

If you want to power up your synthesis, annotate your input types to provide a kernel, a whole, and a converter

One inner synthesizer can work across multiple annotated input types

One class of annotated input types can work across multiple inner synthesizers