From State- to Delta-based Bidirectional Transformations (BXs)

Yingfei Xiong

University of Waterloo

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Content
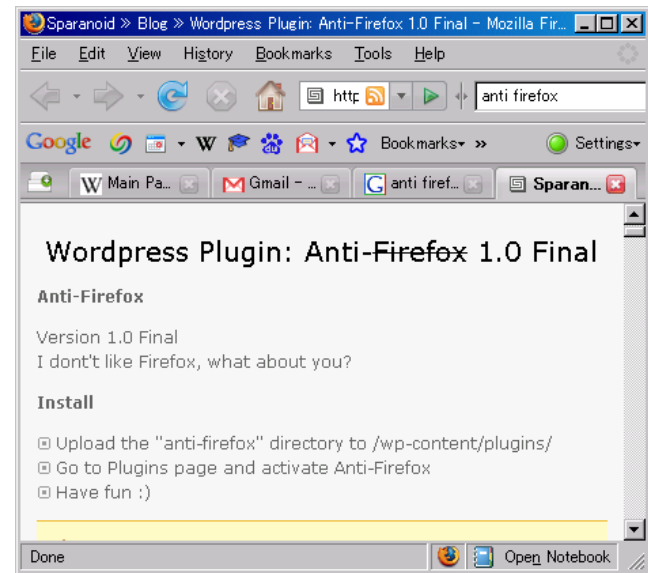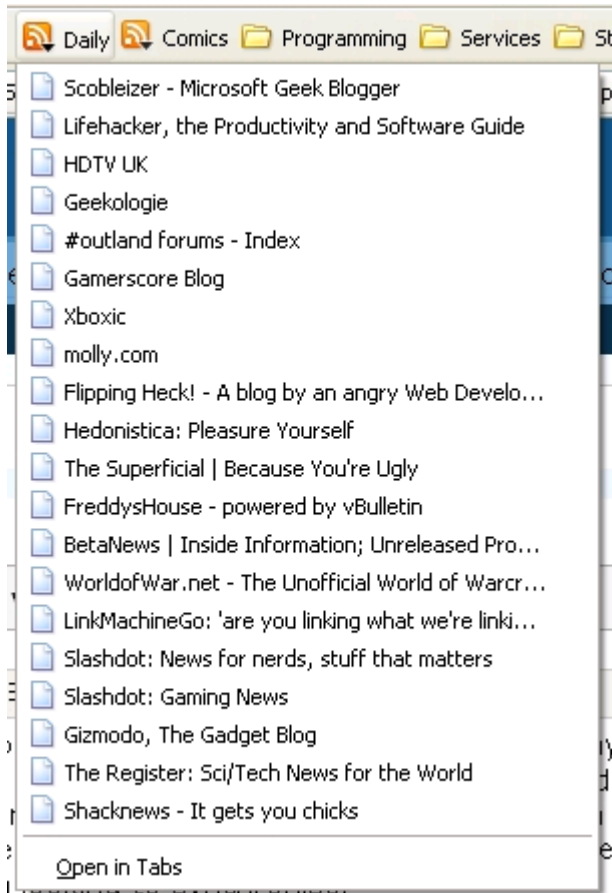
- State-based BXs and related concepts
- Problem of State-based BXs
- Delta-based BXs
- Open Issue: BX laws
- Conclusion

Content

The Problem of Data Interchange

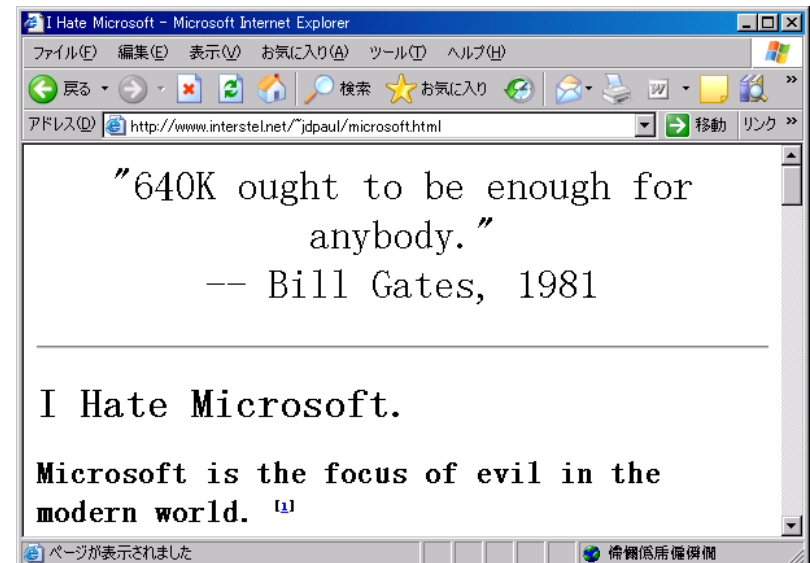- Tom uses Firefox at home, storing a lot of bookmarks

The Problem of Data Interchange

- While in Tom's office the boss requires everyone to use Internet Explorer
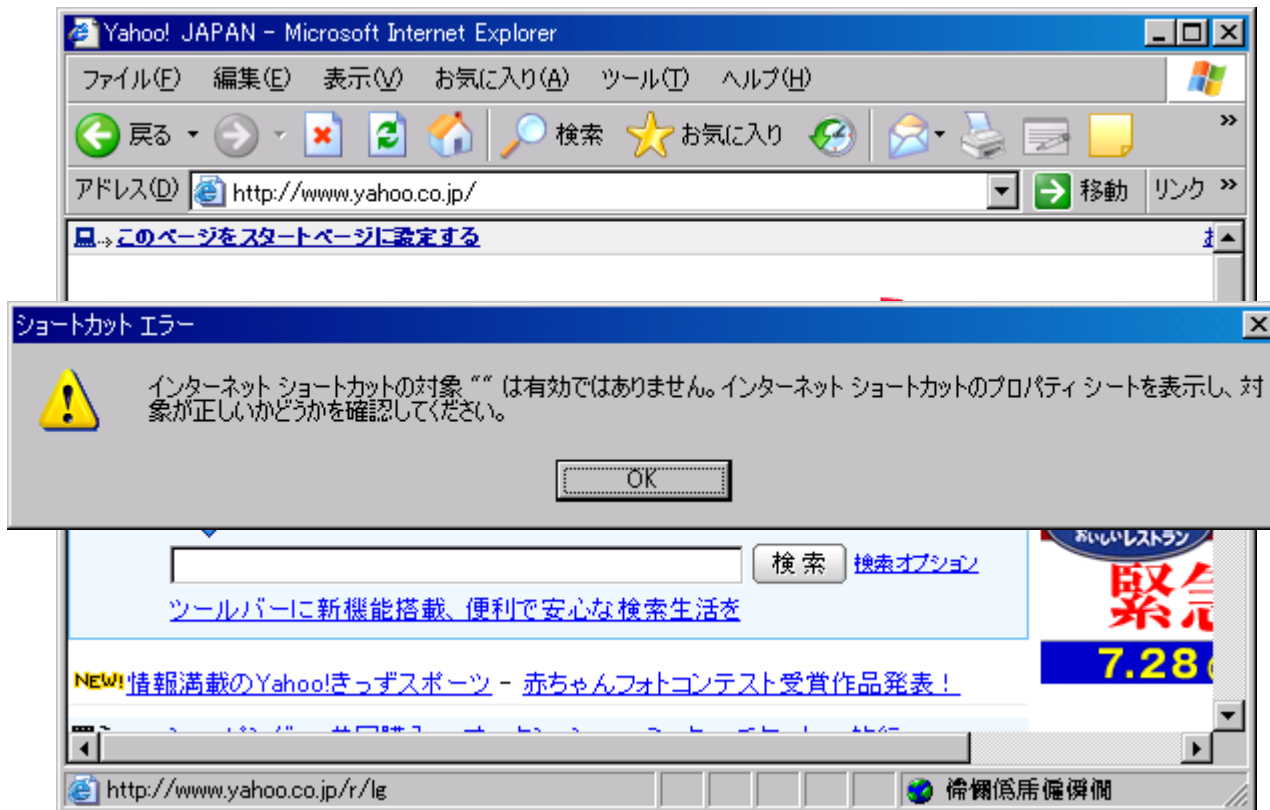

Bill Gates is my brother!
Use IE or be fired!

The Problem of Data Interchange

- So Tom copies the bookmark files from Firefox directory to IE directory

Why the problem

- Data sharing the same information are stored in different formats

Difficulties in Converting Formats

- Data may be stored in a binary format which is rather complex.

  - First 10 bytes is the title following a varying string ended with 0xFFFF

- May be encrypted or indexed.

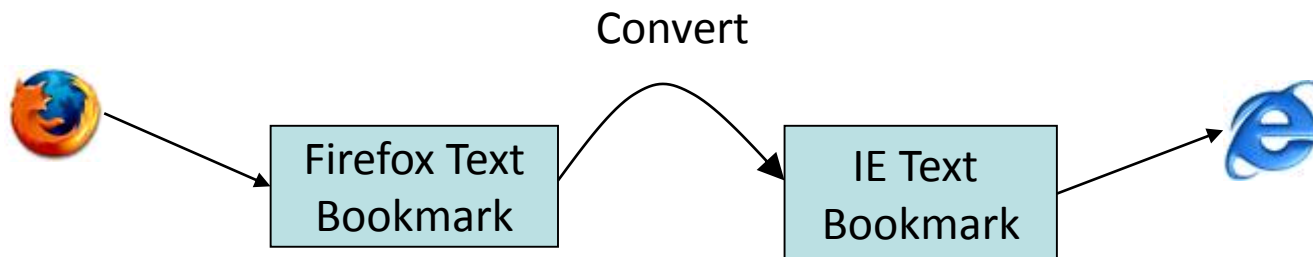- Such a format may be a secret to the company.

Microsoft

Wanna know the bookmark format of IE? I won't tell you.

Intermediate Format

- Export to some intermediate format that is easy to read and process
- Text files and CSV files
  - Lack of structure information
  - Lack of general operations to cope with data

Convert

Firefox Text Bookmark
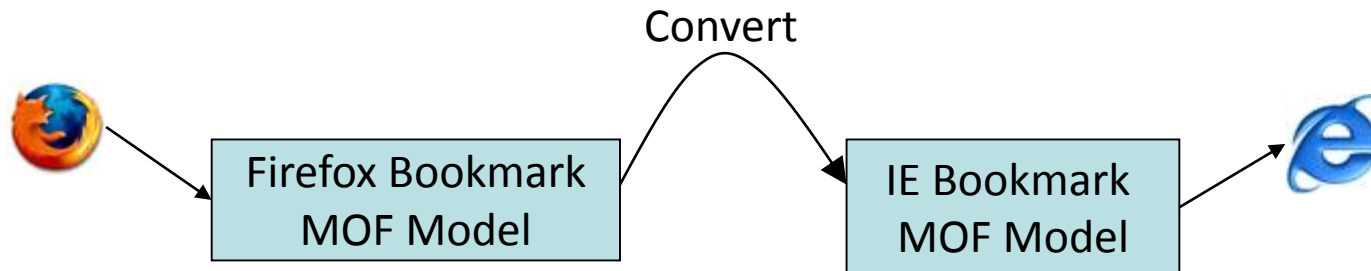
IE Text Bookmark

Standards for Data Interchange

- A standard for data interchange that
  - Provides a generic data structure to describe data
  - Defines how the data are stored into and loaded from files
  - Provides a set of general APIs to operate data
- Two Standards
  - W3C XML
  - OMG MOF

XML and MOF

- XML
  - Proposed by W3C
  - Based on the tree data structure
  - Widely used in general area
- MOF
  - Proposed by OMG
  - Based on the object data structure
  - Originated from Unified Modeling Language
  - Intensively used in software engineering area

Convert

Firefox Bookmark
MOF Model

IE Bookmark
MOF Model
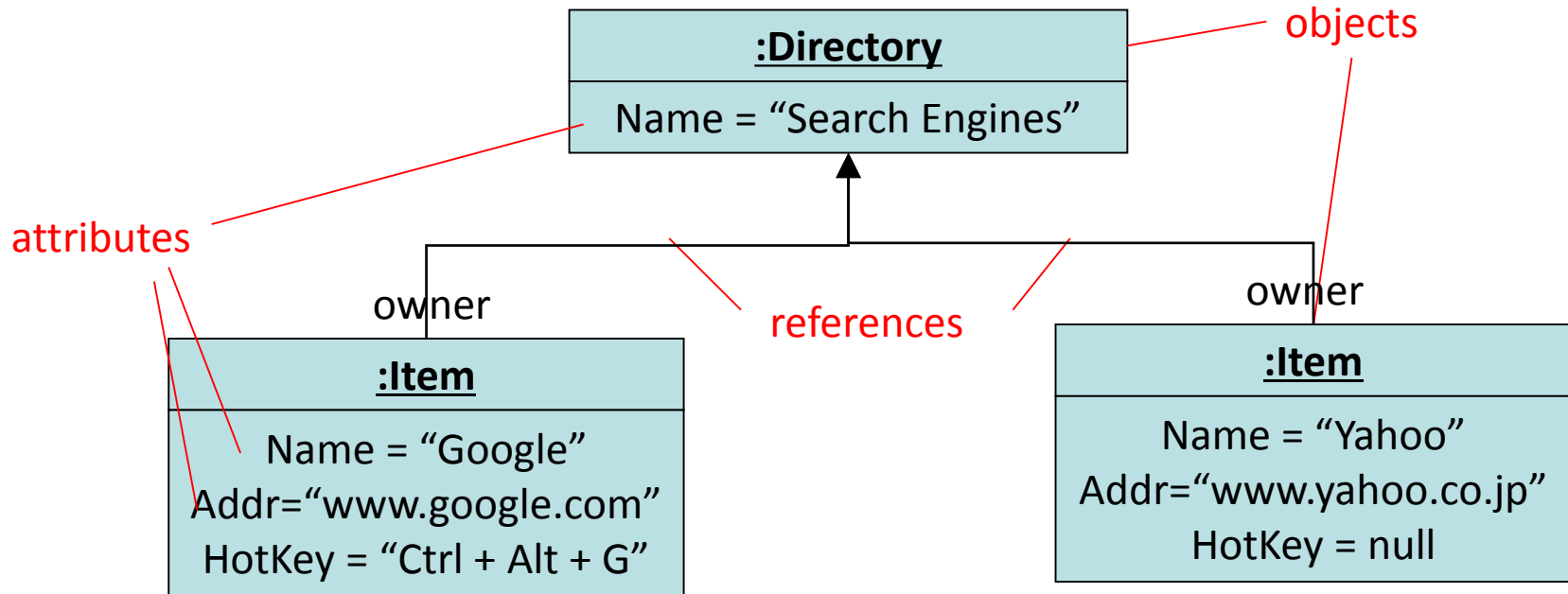
A Possible IE Model

A Possible Firefox Model

:Folder

Name = "Search Engines"
Description = ""

:Folder

Name = "News"
Description = "rss feeds"

Owner

Owner

:Page

Name = "Google"
URL=www.google.com
Desc=Search Engine

:Page

Name = "Yahoo"
URL=www.yahoo.co.jp
Desc=Yahoo Japan Site

Owner

:Rss

Name = "Yahoo News"
URL="news.yahoo.com/feed.rss"
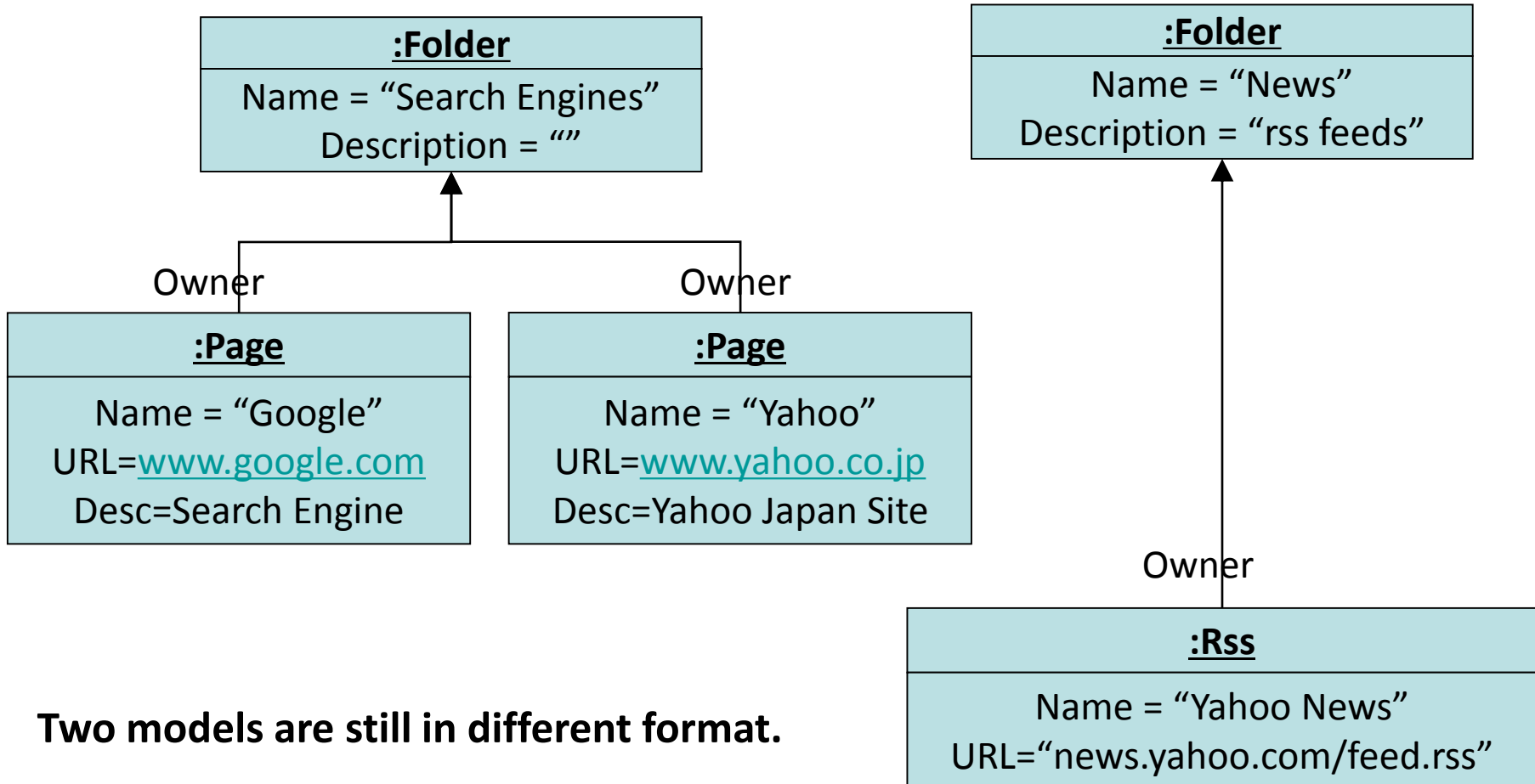
Two models are still in different format.

Content

- State-based BXs and related concepts
  - XML and MOF
  - Transformation Languages
  - Bijective Transformations
  - Bidirectional Transformations
- Problem of State-based BXs
- Delta-based BXs
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Transformation Languages

- Common tasks in format conversion
  - Load and store files
  - Locate to certain objects
  - Read attributes
  - …
- Tedious and error-prone
- Solution: Dedicated Languages for Transformation

Transformation Languages

- Transformation Languages on XML
  - XSLT
  - XQuery
- Transformation Languages on MOF
  - QVT
  - ATL

An ATL Transformation:
```
rule Folder2Directory {
  from f : Firefox!Folder
  to d : IE!Directory {
    Name <- f.Name
  }
}

rule Page2Item {
  from p : Firefox!Page
  to i : IE!Item{
    Name <- p.Name
    Addr <- p.URL
    Owner <- p.Owner
  }
}
```
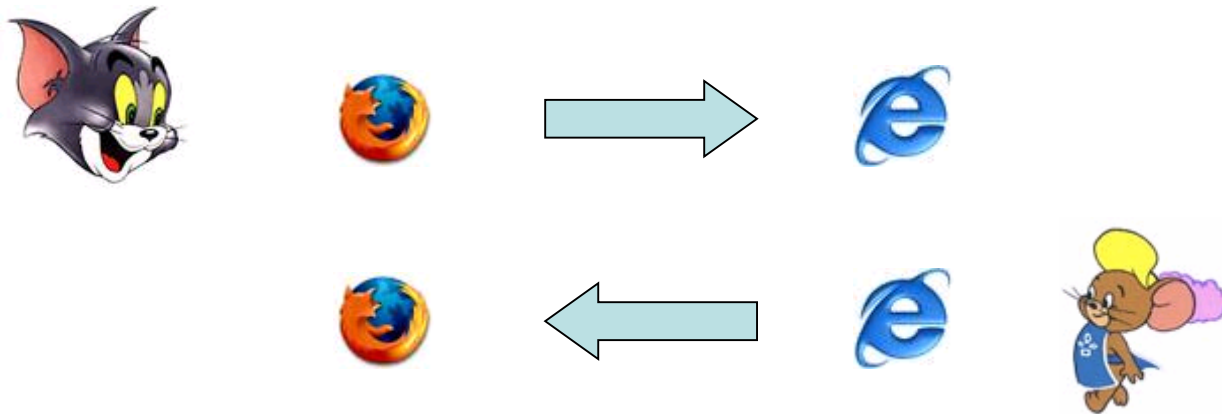
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The Backward Transformation Problem

- What if another guy Jerry wants to transform IE Bookmarks into FireFox?

The Simple Solution

FireFox to IE Transformation:
rule Folder2Directory {
 from f : Firefox!Folder
 to d : IE!Directory {
  Name <- f.Name
 }
}

rule Page2Item {
 from p : Firefox!Page
 to i : IE!Item{
  Name <- p.Name,
  Addr <- p.URL,
  Owner <- p.Owner
 }
}

IE to FireFox Transformation:
rule Directory2Folder {
 from d : IE!Directory
 to f : Firefox!Folder {
  Name <- d.Name
 }
}

rule Page2Item {
 from i : IE!Item
 to p : Firefox!Page {
  Name <- i.Name,
  URL <- i.Addr,
  Owner <- i.Owner
 }
}

The two transformations are very similar and contain duplicate information
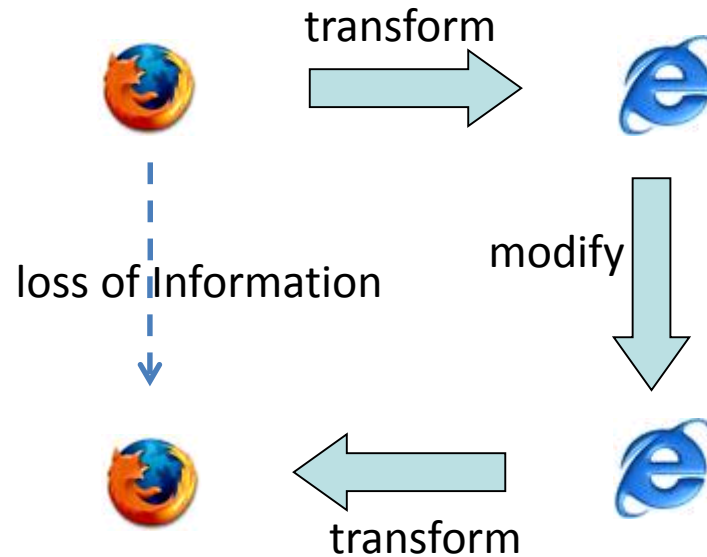
Bijective Transformations

- Can we generate one transformation from the other?
- The Bijective Transformation Languages
  - Inv
  - BOTL
- Use symmetric rules that can be executed forwardly and backwardly

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The Synchronization Problem

- What if Tom changes the IE bookmarks in his office?

transform

loss of Information

modify

transform

Bidirectional Transformations (BXs)

- If the one model is modified, how to reflect the modifications back into the other model
- View Updating in Database
  - When a view is modified, how to reflect the modifications back into original databases
- Bidirectional Transformation Languages on trees
  - Boomerang
  - BiX
- Bidirectional Transformation Languages on graphs
  - QVT
  - TGG

State-based BX

- **Consistency Relation**
  - *R:A×B*

- **Forward Propgation**
  - *fPpg : A×A×B→B*

- **Backward Propagation**
  - *bPpg : A×B×B→A*

Example

Model IE

i2:Item

Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1:Item

Name=Google CN
Addr=google.cn
Hotkey=Alt+g

Model Firefox

p1:Page

Name=Google
URL=google.com
Desc=Search English

p2:Page

Name=Google CN
URL=google.cn
Desc=Search Chinese
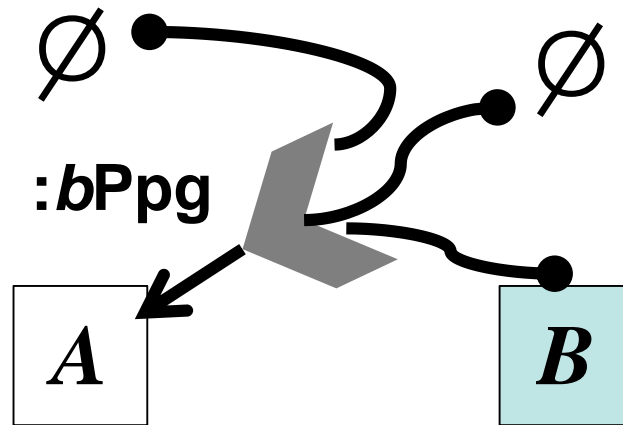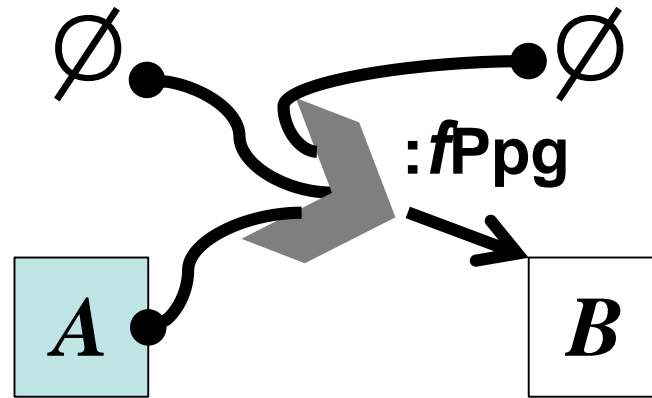
:*b*Ppg

Model IE'

i2':Item

Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1':Item

Name=Google CN
Addr=google.com
Hotkey=Alt+g

Model Firefox'

p1':Page

Name=Google
URL=google.com
Desc=Search English

p2':Page

Name=Google CN
URL=google.com
Desc=Search Chinese

BX subsumes Bijective Transformations

Nothing is guaranteed

Model IE

i2:Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1:Item
Name=Google CN
Addr=google.cn
Hotkey=Alt+g

Model Firefox

p1:Page
Name=Google
URL=google.com
Desc=Search English

p2:Page
Name=Google CN
URL=google.cn
Desc=Search Chinese

:_b_Ppg

Model IE'

i2':Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1':Item
Name=Baidu
Addr=Baidu.com
Hotkey=Alt+b

Model Firefox'

p1':Page
Name=Google
URL=google.com
Desc=Search English

p2':Page
Name=Google CN
URL=google.com
Desc=Search Chinese

Laws of BX: Consistency
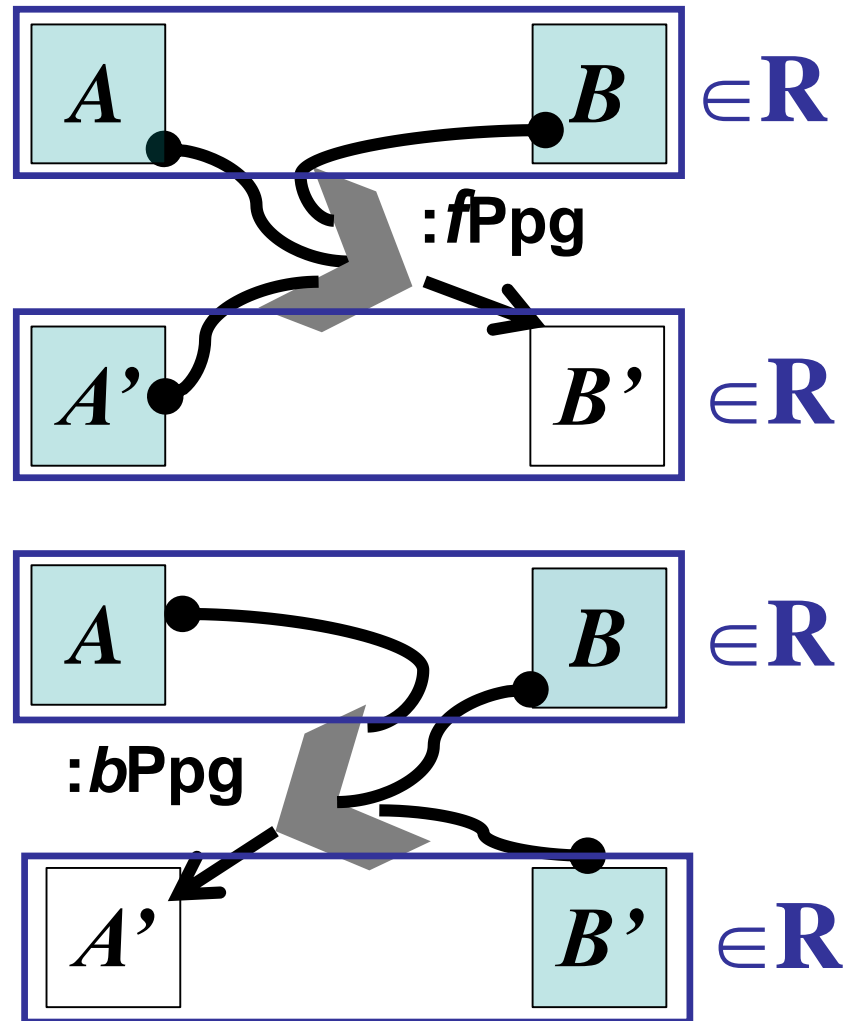
Laws of BX: Identity Propagation
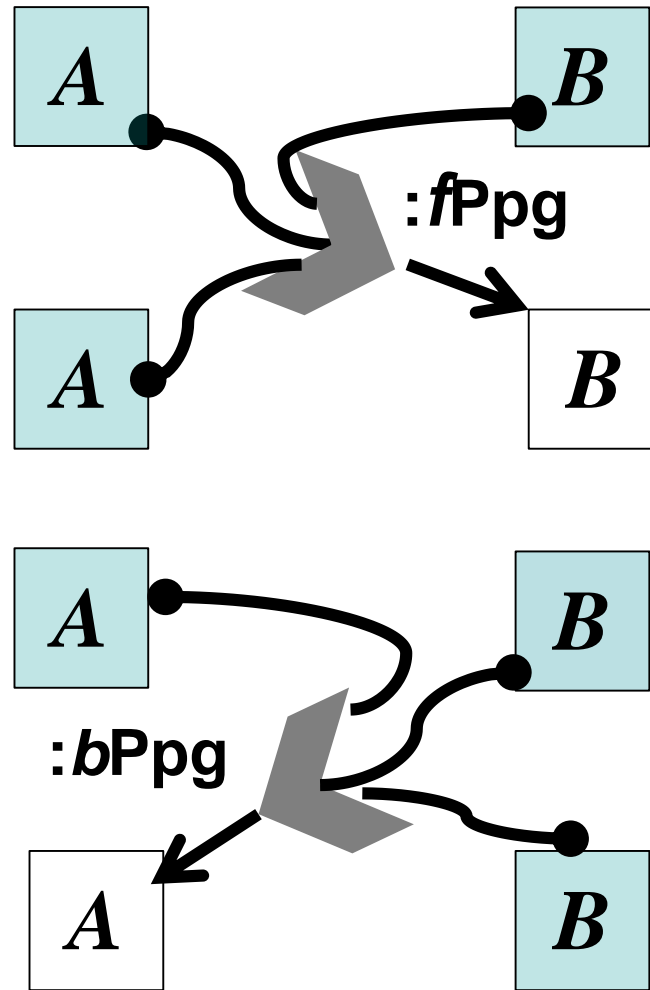
How to write BXs

- Write R, fPpg, bPpg, respectively
  - Duplicated work
  - Error-prone

Bidirectional Languages

Bidirectional Program

Compile

R

fPpg

bPpg
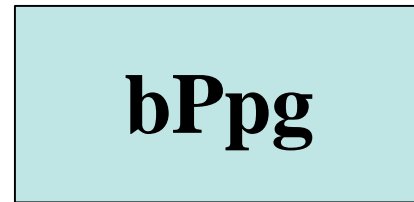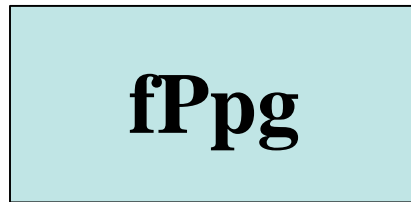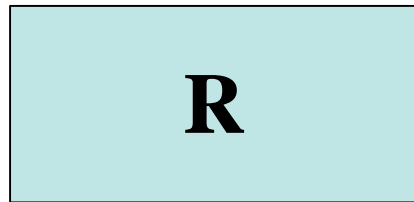
Bidirectional Languages

Atomic BXs + Combinators

Atomic BX: filter[*attr*]

- R: Left – attr = Right
- Filter[HotKey].R

Model IE2

i2:Item	i1:Item
Name=Google Addr=google.com Hotkey=Ctrl+g	Name=Google CN Addr=google.cn Hotkey=Alt+g

Model IE2

i2:Item	i1:Item
Name=Google Addr=google.com	Name=Google CN Addr=google.cn

Atomic BX: filter[Hotkey].fPpg

Model IE1

i2:Item	i1:Item
Name=Google Addr=google.com Hotkey=Ctrl+g	Name=Google CN Addr=google.cn Hotkey=Alt+g

Model IE2

i2:Item	i1:Item
Name=Google Addr=google.com	Name=Google CN Addr=google.cn

:filter[Hotkey].*f*Ppg

Model IE1'

i2':Item	i1':Item
Name=Google Addr=google.com Hotkey=Ctrl+g	Name=Google CN Addr=google.com Hotkey=Alt+g

Model IE2

i2':Item	i1':Item
Name=Google Addr=google.com	Name=Google CN Addr=google.com
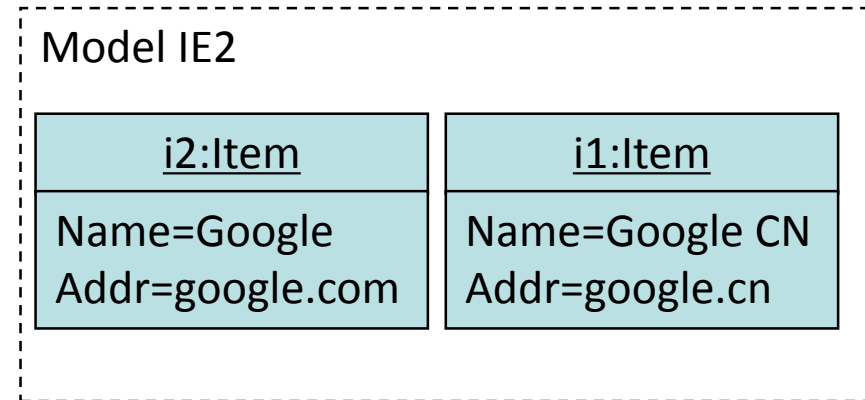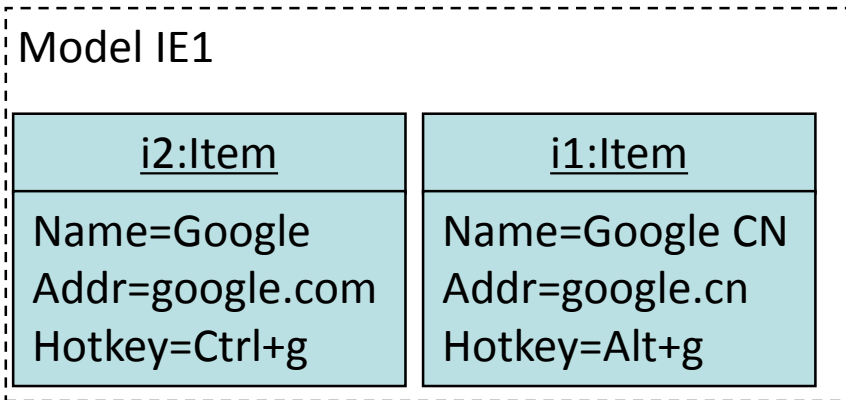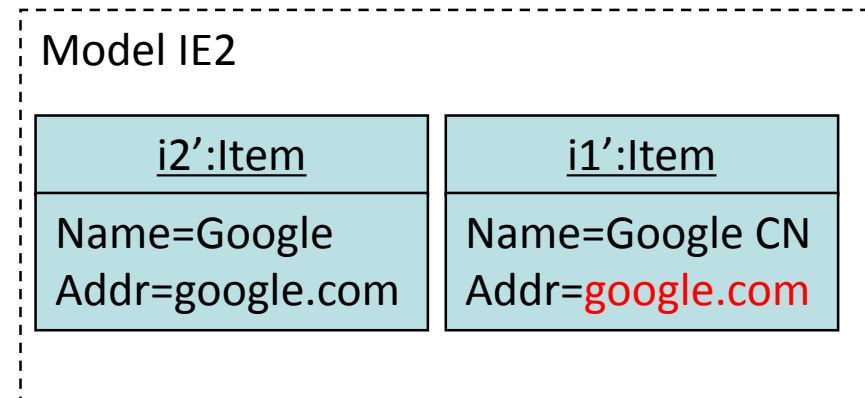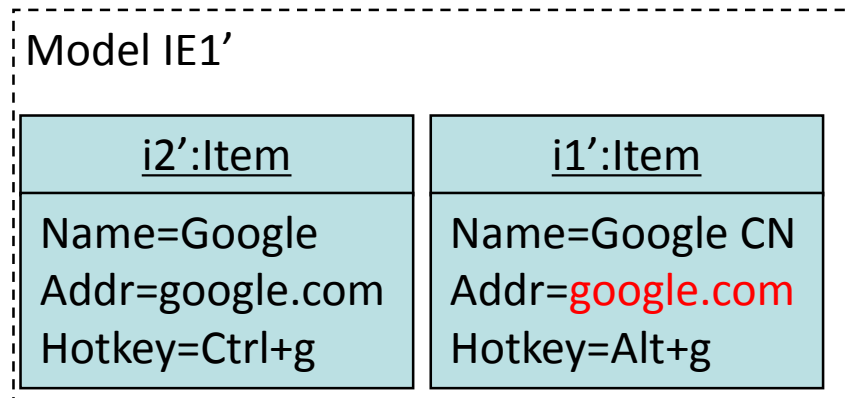
Combinator: Sequential Composition X;Y

- X.R is a function
- (X;Y).R=X.R;Y.R
- (X;Y).fPpg

X;Y satisfies the laws as long as X and Y do

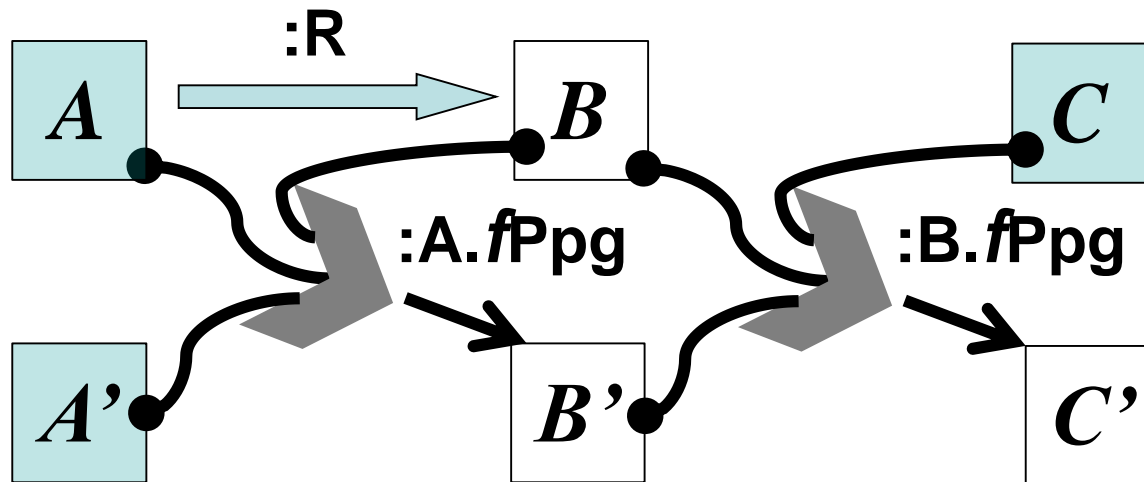# An Example Program

```
┌─ Model IE ──────────────────────────────┐   ┌─ Model Firefox ─────────────────────────┐
│                                          │   │                                         │
│  ┌─────────────────┬─────────────────┐   │   │  ┌─────────────────┬─────────────────┐  │
│  │     i2:Item     │     i1:Item     │   │   │  │     p1:Page     │     p2:Page     │  │
│  ├─────────────────┼─────────────────┤   │   │  ├─────────────────┼─────────────────┤  │
│  │ Name=Google     │ Name=Google CN  │   │   │  │ Name=Google     │ Name=Google CN  │  │
│  │ Addr=google.com │ Addr=google.cn  │   │   │  │ URL=google.com  │ URL=google.cn   │  │
│  │ Hotkey=Ctrl+g   │ Hotkey=Alt+g    │   │   │  │ Desc=Search     │ Desc=Search     │  │
│  │                 │                 │   │   │  │     English     │     Chinese     │  │
│  └─────────────────┴─────────────────┘   │   │  └─────────────────┴─────────────────┘  │
└──────────────────────────────────────────┘   └─────────────────────────────────────────┘
```

filter[Hotkey];

renameAttribute[Addr, URL];

renameClass[Item, Page];

inverse[filter[Desc]]

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Delta Interpretation 1

Model IE

i2:Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1:Item
Name=Google CN
Addr=google.cn
Hotkey=Alt+g

Model Firefox

p1:Page
Name=Google
URL=google.com
Desc=Search English

p2:Page
Name=Google CN
URL=google.cn
Desc=Search Chinese

:*b*Ppg

p1=p1'
p2=p2'

Model IE'

i2':Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1':Item
Name=Google CN
Addr=google.com
Hotkey=Alt+g

Model Firefox'

p1':Page
Name=Google
URL=google.com
Desc=Search English

p2':Page
Name=Google CN
URL=google.com
Desc=Search Chinese

Delta Interpretation 2

Model IE

i2:Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1:Item
Name=Google CN
Addr=google.cn
Hotkey=Alt+g

Model Firefox

p1:Page
Name=Google
URL=google.com
Desc=Search English

p2:Page
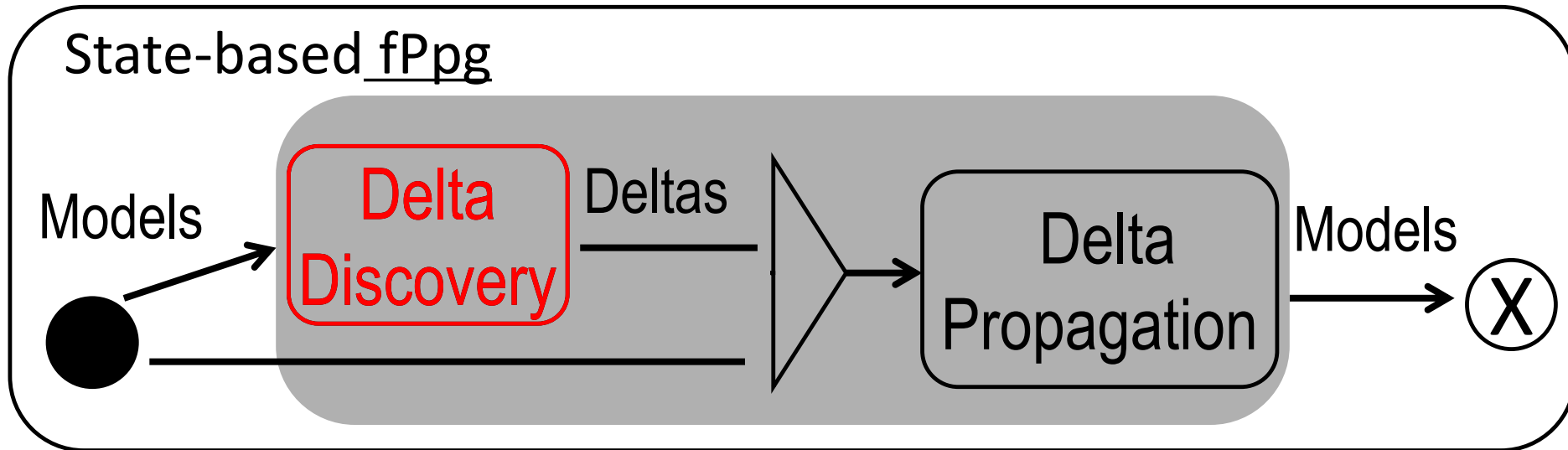Name=Google CN
URL=google.cn
Desc=Search Chinese

:*b*Ppg

p1=p1'

Model IE'

i2':Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1':Item
Name=Google CN
Addr=google.com
Hotkey=null

Model Firefox'

p1':Page
Name=Google
URL=google.com
Desc=Search English

p2':Page
Name=Google CN
URL=google.com
Desc=Search Chinese

39

Problem 1 of State-based BX

State-based fPpg

Models

Delta Discovery

Deltas

Delta Propagation
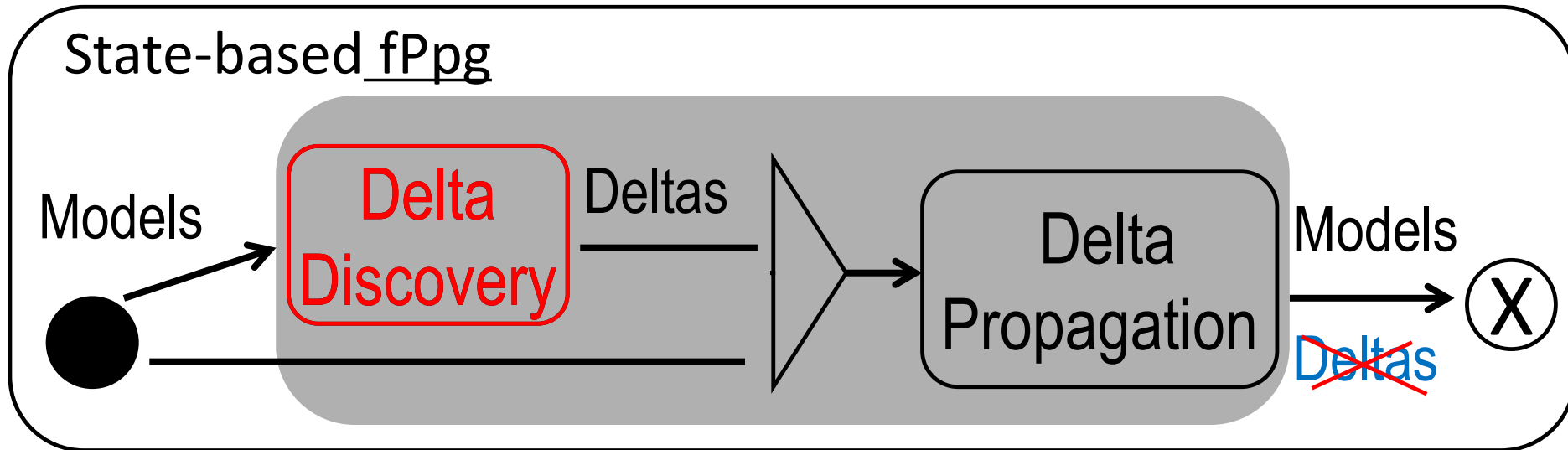
Models

X

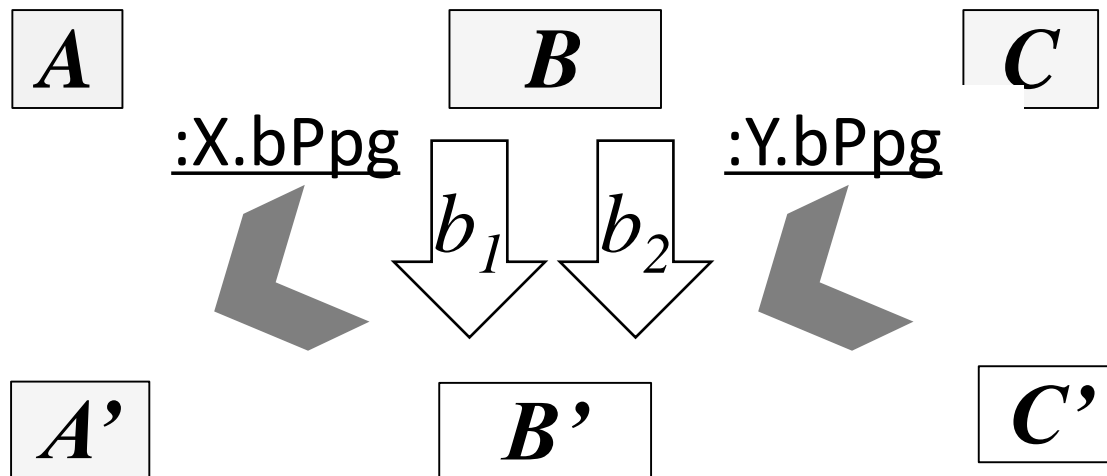- Semantics of DD is mixed into DP, complicating the latter
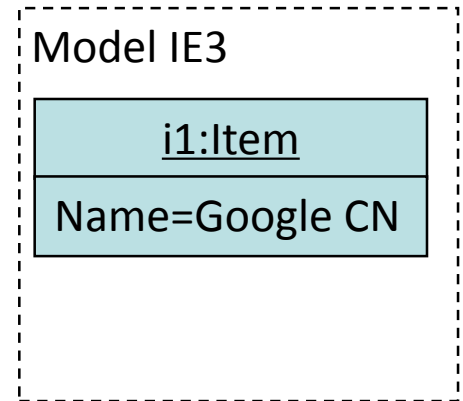
Problem 2 of State-based BX

- New deltas are discarded, causing composition problem

Erroneous Sequential Composition

A B C

:X.bPpg   :Y.bPpg

b_1 b_2

A' B' C'

Efficiency: X.bPpg has to compute the delta again
Semantics: X.bPpg may compute a different delta

filter[Hotkey]; filter[Addr]

Model IE1

i1:Item

Name=Google CN
Addr=google.cn
Hotkey=Alt+g

Model IE2

i1:Item

Name=Google CN
Addr=google.cn

Model IE3

i1:Item

Name=Google CN

:filter[Hotkey].*b*Ppg

i1≠i1'

i1=i1'

:filter[Addr].*b*Ppg

Model IE1'

i1':Item

Name=谷歌中国
Addr=google.cn
Hotkey=null

Model IE2'

i1':Item

Name=谷歌中国
Addr=google.cn

Model IE3'

i1':Item

Name=谷歌中国

Horizontal Delta Interpretation 1

Model IE

i2:Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1:Item
Name=Google CN
Addr=google.com
Hotkey=Alt+g

i1=p2
i2=p1

Model Firefox

p1:Page
Name=Google
URL=google.com
Desc=Search English

p2:Page
Name=Google CN
URL=google.cn
Desc=Search Chinese

i1=i1'
i2=i2'

:fPpg

Model IE'

i2':Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1':Item
Name=Baidu
Addr=baidu.com
Hotkey=Alt+g

Model Firefox'

p1':Page
Name=Google
URL=google.com
Desc=Search English

p2':Page
Name=Baidu
URL=baidu.com
Desc=Search Chinese

Horizontal Delta Interpretation 2

i1=p1
i2=p2

Model IE

i2:Item	i1:Item
Name=Google Addr=google.com Hotkey=Ctrl+g	Name=Google CN Addr=google.com Hotkey=Alt+g

Model Firefox

p1:Page	p2:Page
Name=Google URL=google.com Desc=Search English	Name=Google CN URL=google.cn Desc=Search Chinese

i1=i1'
i2=i2'

:fPpg

Model IE'

i2':Item	i1':Item
Name=Google Addr=google.com Hotkey=Ctrl+g	Name=Baidu Addr=baidu.com Hotkey=Alt+g

Model Firefox'

p1':Page	p2':Page
Name=Baidu URL=baidu.com Desc=Search English	Name=Google URL=google.com Desc=Search Chinese

Erroneous vertical composition
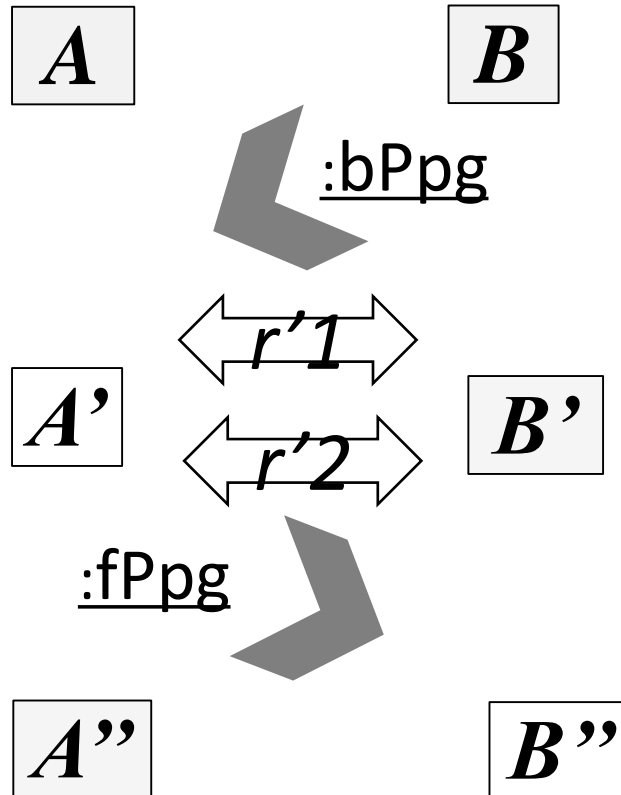
A

B

:bPpg

$r'1$

A'

B'

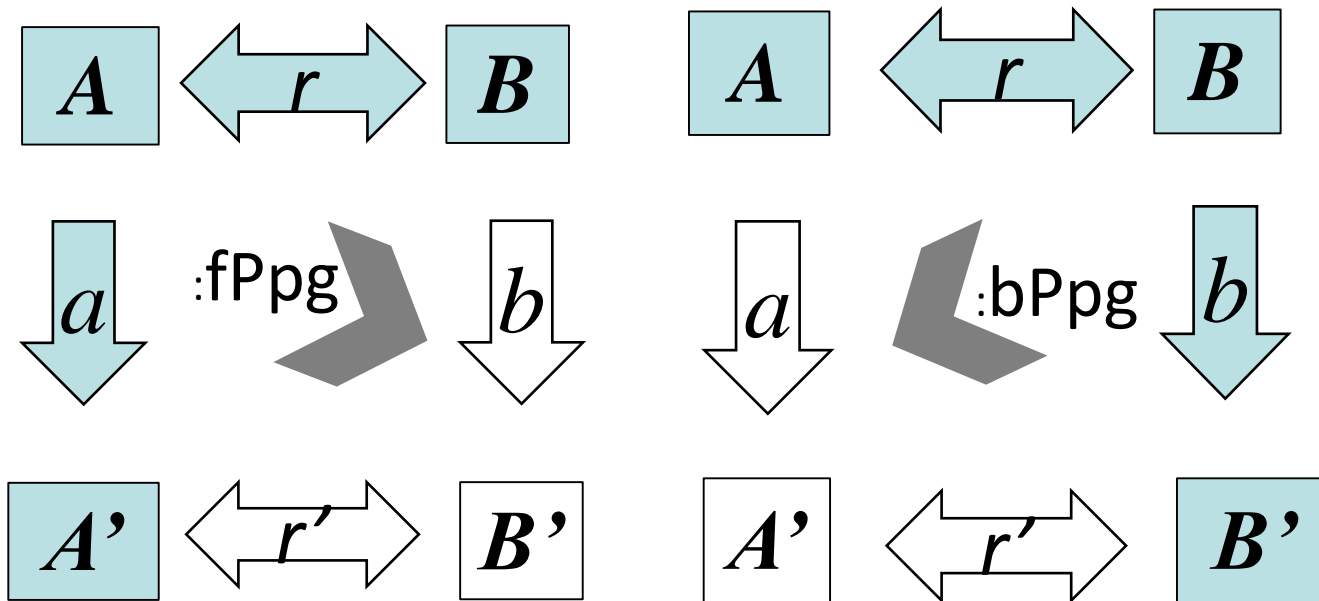$r'2$

:fPpg

A''

B''

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Delta-based BX

R: a set of deltas between two model spaces
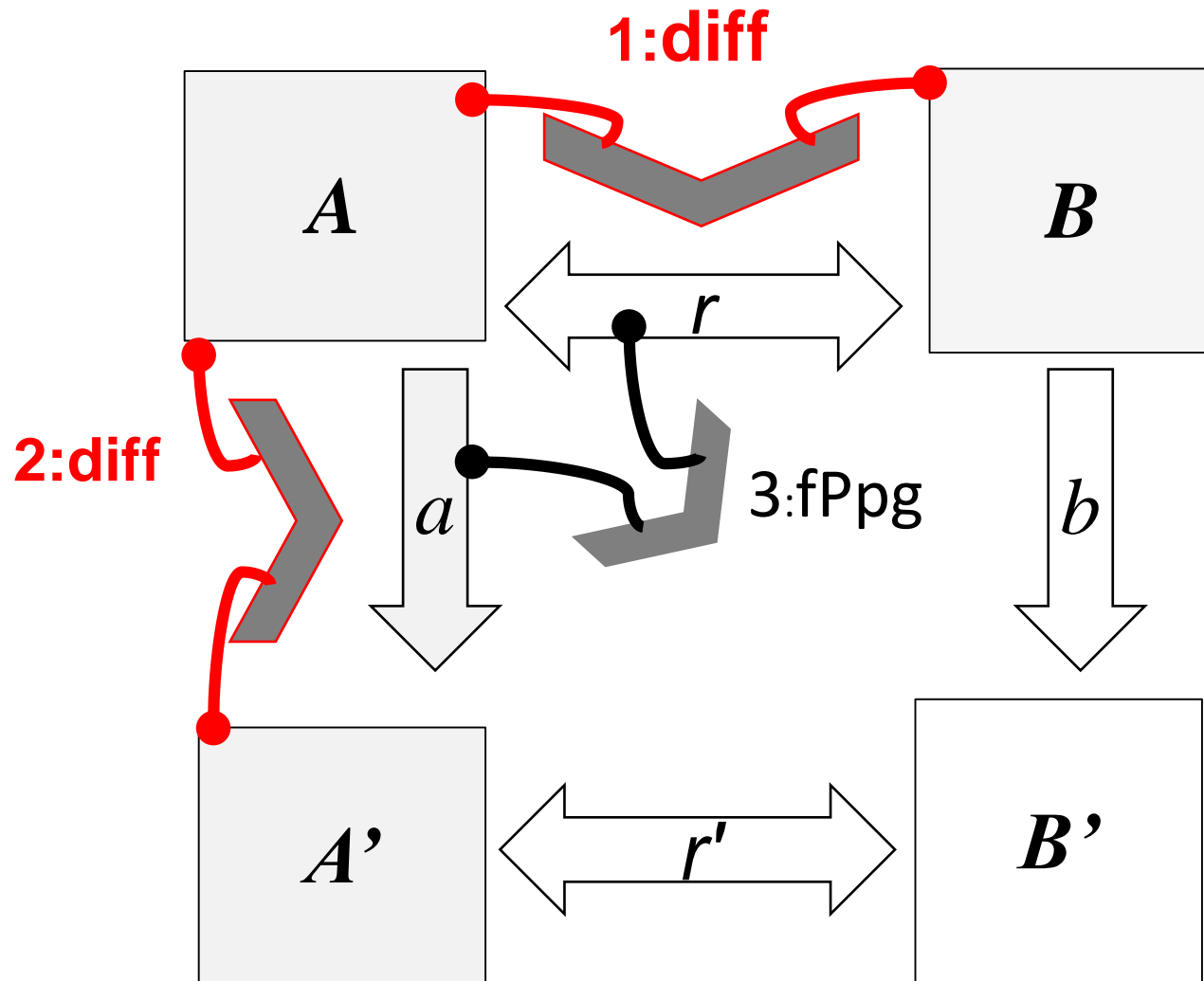

Forward update propagation

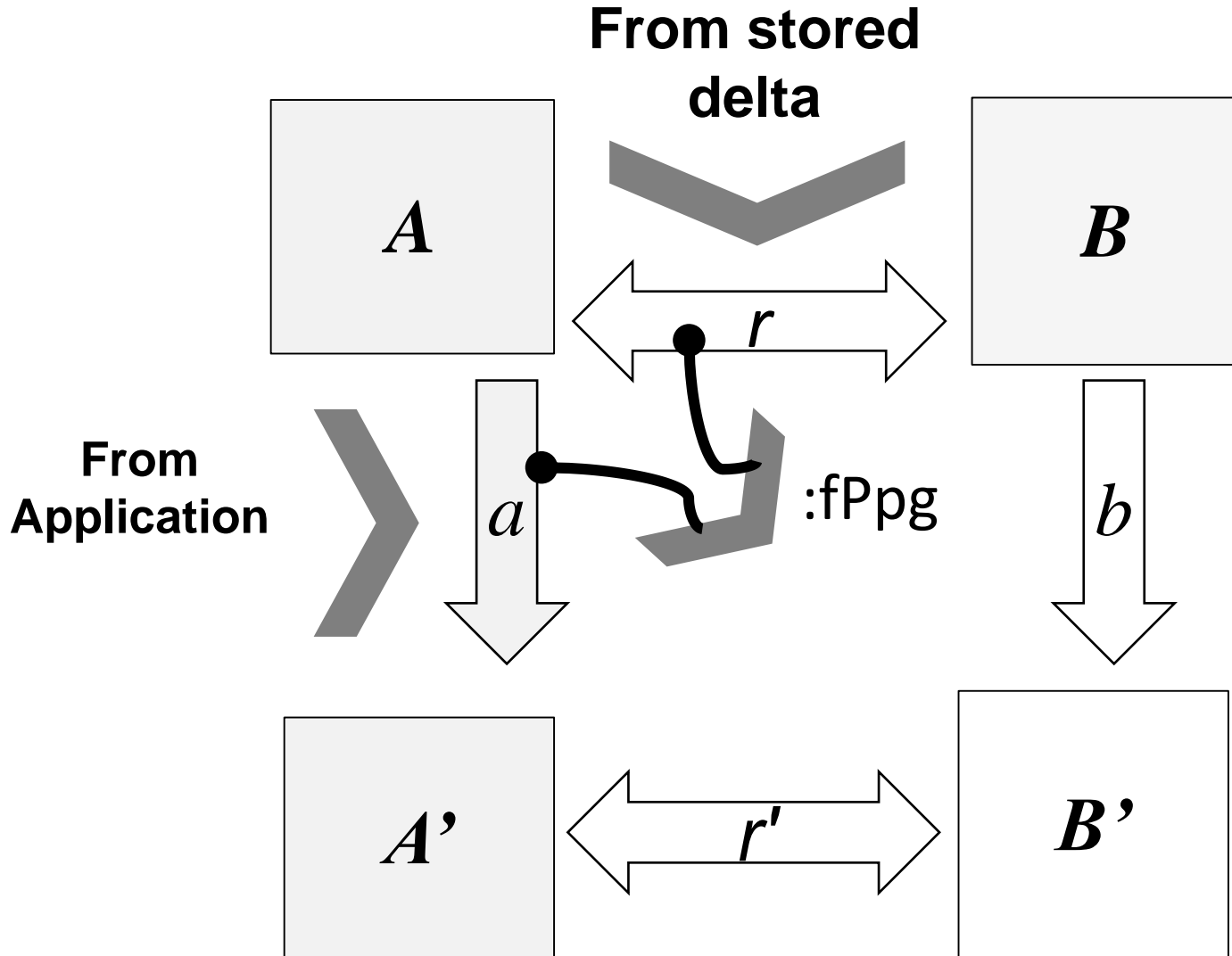Backward update propagation

Benefits

- Honest math model
- Semantics of DD and DP are separated
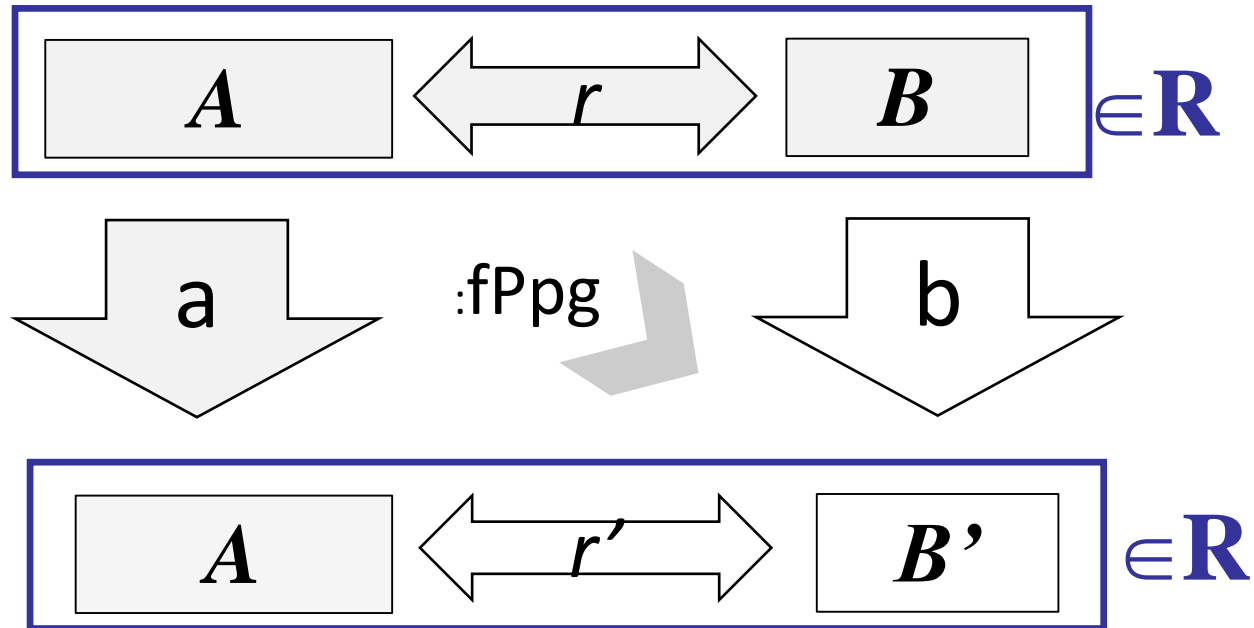- No composition problem
- More flexible
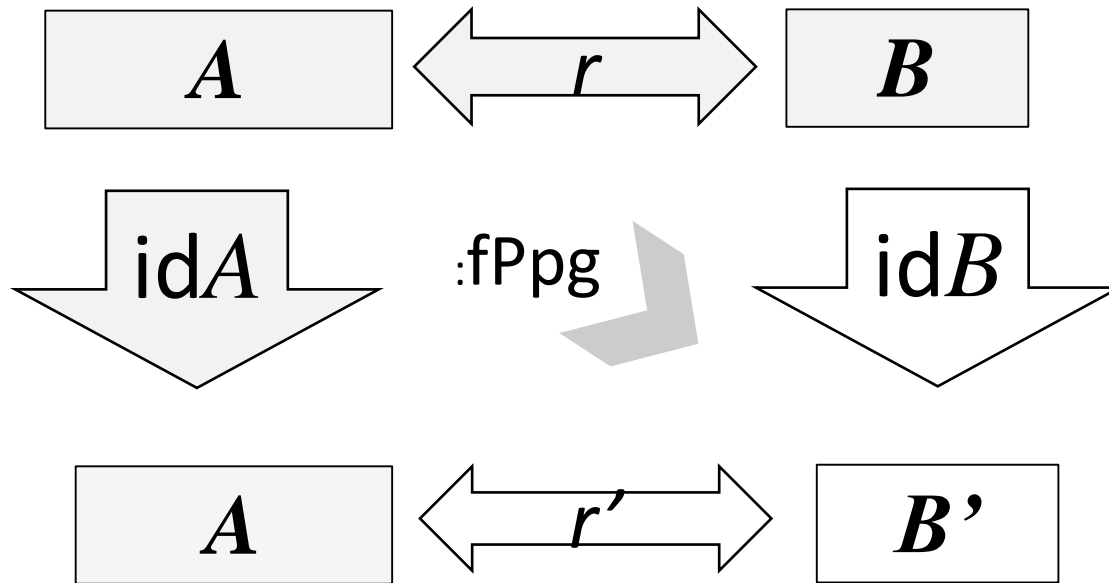
From delta- to state-based

Flexibility of Delta-based BX

Delta-based laws: Consistency

Delta-based laws: Identity propagation

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BX laws are inadequate

Model IE

i2:Item
Name=Google Addr=google.com Hotkey=Ctrl+g

i1:Item
Name=Google CN Addr=google.cn Hotkey=Alt+g

Model Firefox

p1:Page
Name=Google URL=google.com Desc=Search English

p2:Page
Name=Google CN URL=google.cn Desc=Search Chinese

:fPpg

Model IE'

i2':Item
Name=Google Addr=google.com Hotkey=Ctrl+g

i1':Item
Name=Google CN Addr=google.com Hotkey=Alt+g

Model Firefox'

p1':Page
Name=Google URL=google.com Desc=Search French

p2':Page
Name=Google CN URL=google.com Desc=Search Chinese

Extra laws are proposed

Undoability law [Stevens'07]
B'' = B
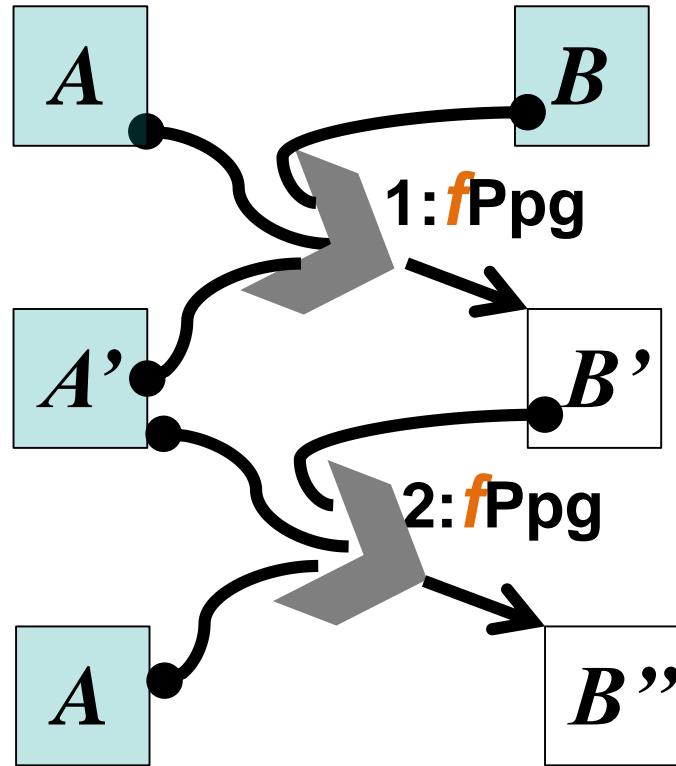
- PUTPUT law [Nate et al. 05]
- Invertibility law [Diskin08]
- Composability law [Xiong et al. 07]

Undoability solves the problem

Model IE

i2:Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1:Item
Name=Google CN
Addr=google.com
Hotkey=Alt+g

Model Firefox

p1:Page
Name=Google
URL=google.com
Desc=Search French

p2:Page
Name=Google CN
URL=google.com
Desc=Search Chinese

:fPpg

Model IE'

i2':Item
Name=Google
Addr=google.com
Hotkey=Ctrl+g

i1':Item
Name=Google CN
Addr=google.cn
Hotkey=Alt+g

Model Firefox'

p1':Page
Name=Google
URL=google.com
Desc=Search French

p2':Page
Name=Google CN
URL=google.cn
Desc=Search Chinese

≠Search English

But is too strong

i1:Item
Name=Google CN Addr=google.cn Hotkey=Alt+g

p2:Page
Name=Google CN URL=google.cn Desc=Search Chinese

:fPpg

∅

∅

:fPpg

i1:Item
Name=Google CN Addr=google.cn Hotkey=Alt+g

p2:Page
Name=Google CN URL=google.cn Desc=null
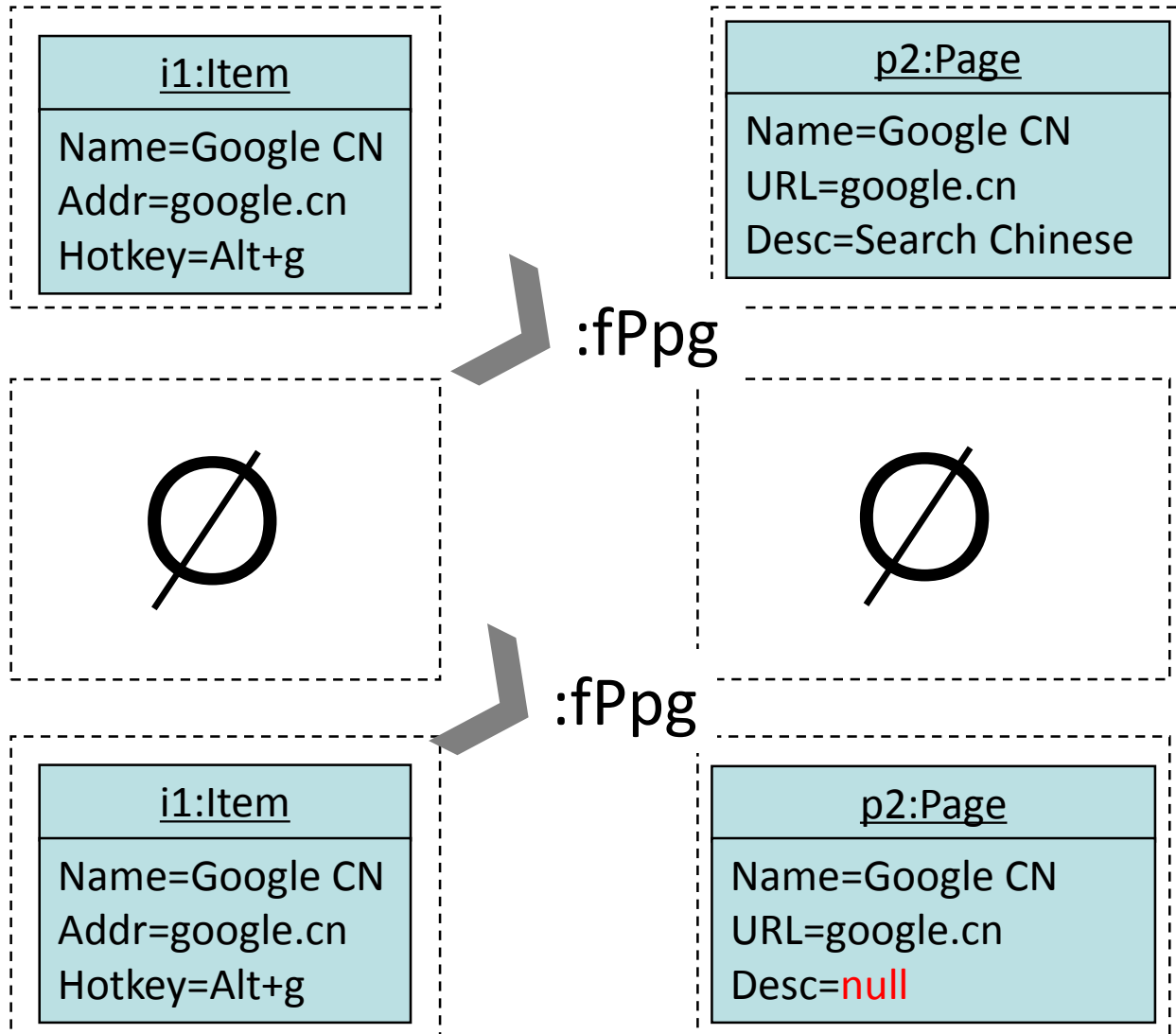
Current Status

- Weak undoability and weak invertibility are proposed on delta-based BX [Diskin, Xiong, Czarnecki. MODELS'11]

- Laws are still inadequate

Content

- State-based BXs and related concepts
- Problem of State-based BXs
- Delta-based BXs
- Open Issue: BX laws
- Conclusion

Conclusion

- BXs are useful in data synchronization
- Deltas are crucial in BXs
- Delta-based BXs
  - Honest math model
  - Solve the problems in state-based BXs
  - More Flexible
- BX laws are still an open problem