Collage: A Declarative Programming Model for Compositional Development and Evolution of Cross-Organizational Applications

Bruce Lucas, IBM T J Watson Research Center (bdlucas@us.ibm.com)
Charles F Wiecha, IBM T J Watson Research Center (wiecha@us.ibm.com)

Collage Motivation and Goals

- Motivated by a mismatch
  - today's applications are loosely coupled, inter-organizational, inter-networked
  - but programming models are designed for monolithic, freestanding applications

- Collage programming model goals
  - targeted at cross-organizational software
    - programs are built as compositions of web components
    - inherently distributed data, execution, development models
  - highly composable
    - fine-grained "gray-box" aspect-like composition
    - supports loosely coupled cross-organizational development
  - declarative
    - focuses on "what" not "how"
    - therefore more readily composable
  - support evolutionary style of software development
    - rapid prototyping
    - progressive refinement into a deployed, hardened asset
  - radically simplified
    - uniform end-to-end programming model
    - supports fluidity of application design

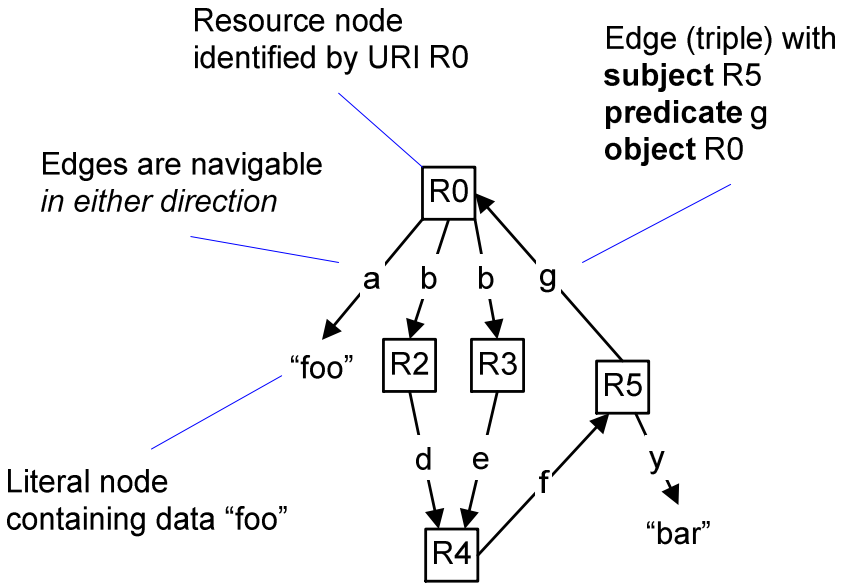
Outline

- Data Model
  - RDF Distributed Graph Data Structures
  - RDF Classification
  - Collage Resources as Mutable Entities
  - Collage/RDF as a Unifying Data Model
  - Examples – XML, relational
- Execution Model
  - Execution Model Concepts
  - Bind Construct
  - Let and Create Constructs
  - End-to-end Example
- Interaction and Composition
  - Recursive MVC
  - Flexible Decomposition and Styling Example
  - Open Composition and Adaptation Example
  - Device Adaptation Example

DATA MODEL

RDF Distributed Graph Data Structures

- Resource: graph node, identified by URI
- Property: graph edge label, named by URI
- Literal: graph data node, as typed string
- Triple: bidirectional graph edge consisting of
  - Subject: resource
  - Predicate: property
  - Object: resource or literal

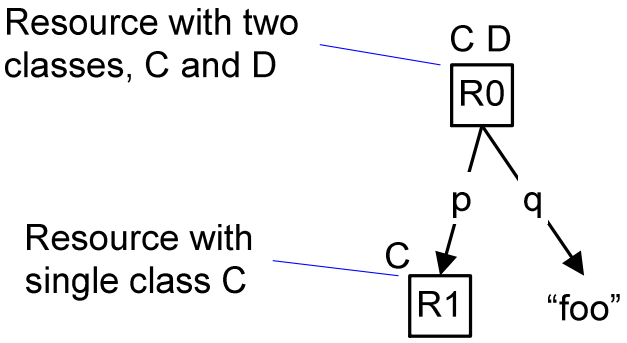


RDF Triple Store

subject	predicate	object
R0	a	"foo"
R0	b	R2
R0	b	R3
R2	d	R4
R3	e	R4
R4	f	R5
R5	y	"bar"
R5	g	R0

RDF Classification

- Resources may be classified
- Classes are named by URIs
- Classifications are represented by triples with property rdf:type
- Multiple classification: a resource may have zero, one, or more classes
- Dynamic classification: a resource's classification may change
- Classifications may originate from disparate development sources
- Implications of classification are not prescribed by RDF



RDF Triple Store

Application data as RDF triples

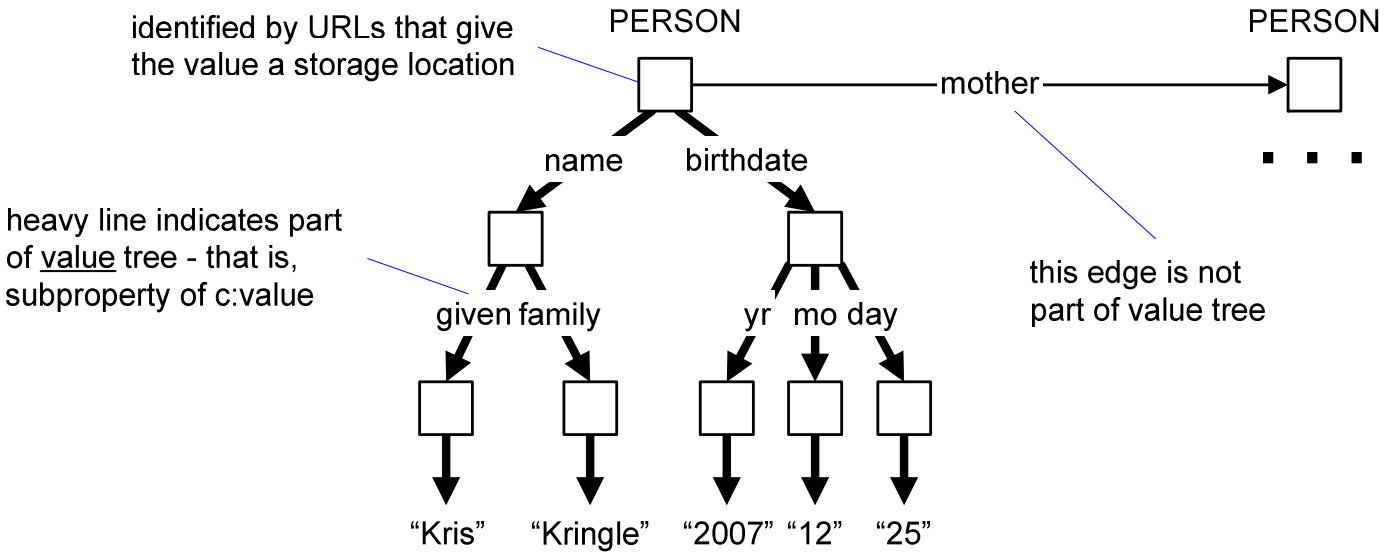
subject	predicate	object
R0	p	R1
R0	q	"foo"

Resource classes as RDF triples

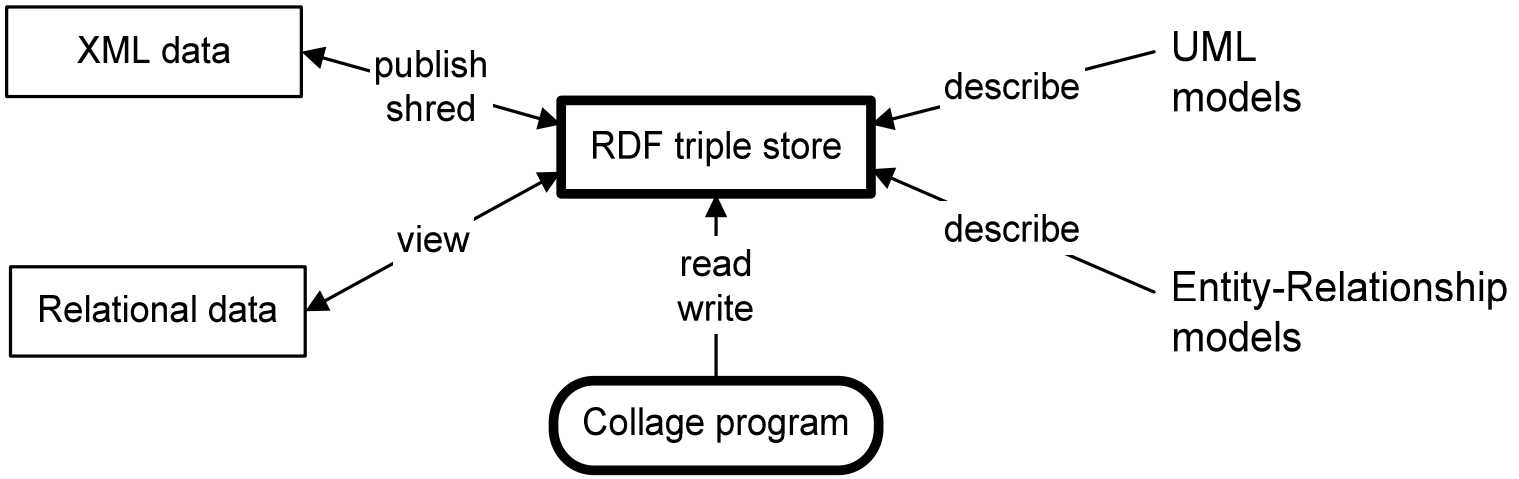
R0	rdf:type	C
R0	rdf:type	D
R1	rdf:type	C

Collage Resources as Mutable Entities

- Collage resources have a composite value
  - recursively composed value, i.e. tree
  - tree of RDF nodes and triples
  - triples forming value distinguished by having property that is subproperty of c:value
- Collage resources have a location
  - identified by URL such as http:
  - value may be read or updated via URL
  - this models mutable entities

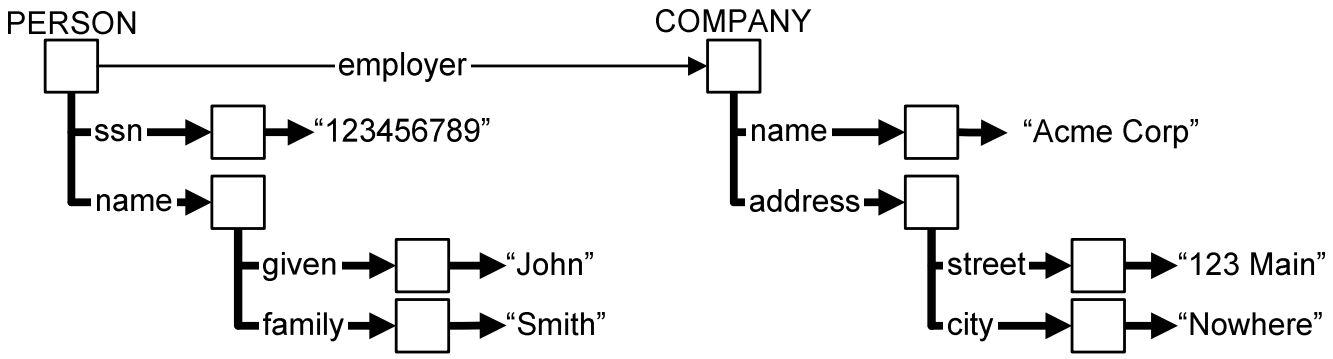


Collage/RDF as a Unifying Data Model



Collage/RDF	Entity-Relationship	UML	Relational	XML
class	entity class	class	table	---
resource	entity instance	object	row	element, attribute
value property	attribute	attribute	column	parent-child relationship
value tree	composite attribute	---	---	XML (sub)-tree
non-value property	---	association	PK/FK	---

XML Data Model Example




```
<PERSON>
   <ssn>123456789</ssn>
   <name>
      <given>John</given>
      <family>Smith</family>
   </name>
</PERSON>
```

```
<COMPANY>
   <name>Acme Corp.</name>
   <address>
      <street>123 Main</street>
      <city>Nowhere</street>
   </address>
</COMPANY>
```

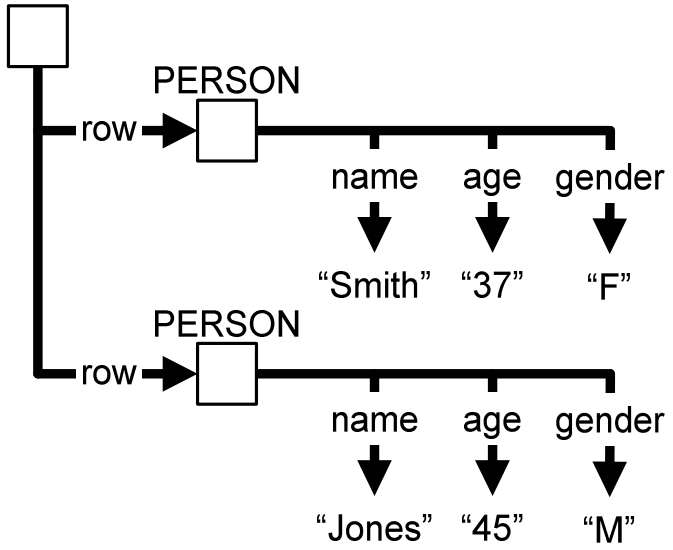
- Uniform data model: RDF triples uniformly represent
  - relationships *within* XML document (e.g. ssn, name, address)
  - relationships *between* XML documents (e.g. employer)
- Allows uniform navigation across entire data model
- Simplifies program and data model refactoring by eliminating data model boundary between intra- and inter-document

Relational Data Model Example

Relational Table

name	age	gender
Smith	37	F
Jones	45	M

RDF representation

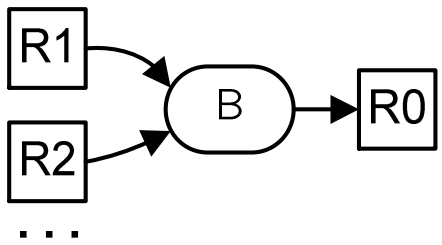


EXECUTION MODEL

Execution Model Concepts

- Reactive: defined in terms of reactions to external events
- Data-centric: defined in terms of evolution of state
  - language semantics
  - data-centric abstraction, refinement, encapsulation, interfaces
- Update-based:
  - an update is an assignment of a value to a resource
  - update is fundamental semantic unit of action
  - all external events manifest as initiating resource updates...
  - ...that cause a cascade of ensuing updates
- Distributed
  - Built on distributed data model
  - Messages as implementation protocol, not programming model
- Declarative language constructs:
  - Bind: spreadsheet-like connection between resource value updates
  - Create: data-driven creation of resources
  - Let: data-driven creation of structure

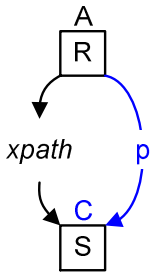
Bind Construct



- Declarative expression of functional relationship between resource values
  - Developer specifies function B to compute output R0 from R1, R2, ...
  - Effectively a one-way conditional constraint on the resource values
  - “Generalized spreadsheet” conceptual model
- May be triggered by an update to an input resource - each input may be
  - active: update to that input triggers execution of bind
  - passive: update to that input does not trigger execution of bind
- Each input may refer to its resource’s
  - new value: value at end of execution cycle
    - used for constraint-like computations
  - old value: value at beginning of execution cycle
    - used for non-idempotent operations such as inserting into a set or adding to a value

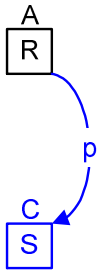
Let and Create Constructs

- Declarative data-driven creation of structure
  - creation of resources
  - classification of resources
  - creation of triples to connect resources




```
<let
    anchor="A"
    path="xpath"
    property="p"
    class="C"/>
```

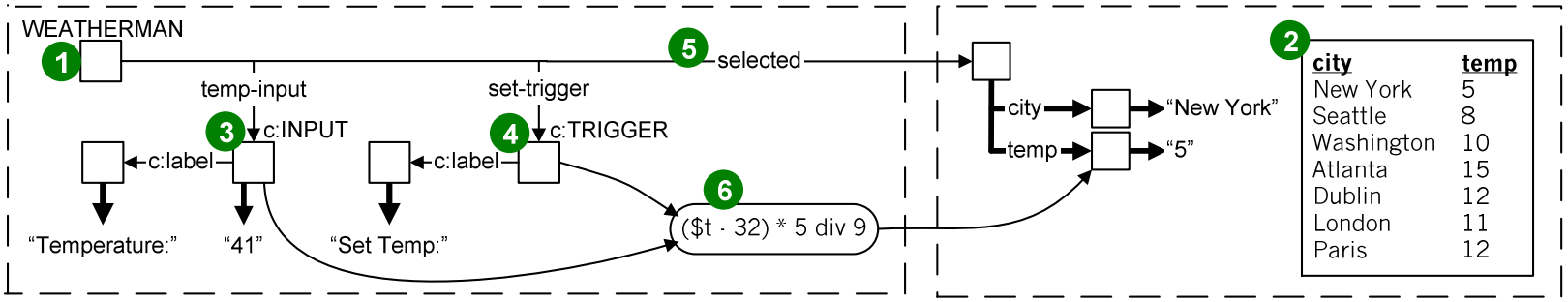
```
for every resource R of class A
    for every resource S reachable by xpath from A
        classify S with class C
        connect R to S with property p
```

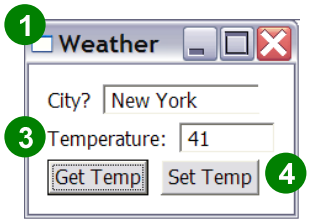



```
<create
    anchor="A"
    property="p"
    class="C"/>
```

```
for every resource R of class A
    create a resource S
    classify S with class C
    connect R to S with property p
```

End-to-End Application Example






```
3 <c:create class="c:INPUT" property="temp-input">
    <c:out path="c:label">Temperature:</c:out>
  </c:create>

4 <c:create class="c:TRIGGER" property="set-trigger">
    <c:out path="c:label">Set Temp</c:out>
  </c:create>

5 <c:let property="selected"
      path="/weather-database/row[city=$city-field]">
    <c:in variable="$city-field" path="city-field"/>
  </c:let>
```

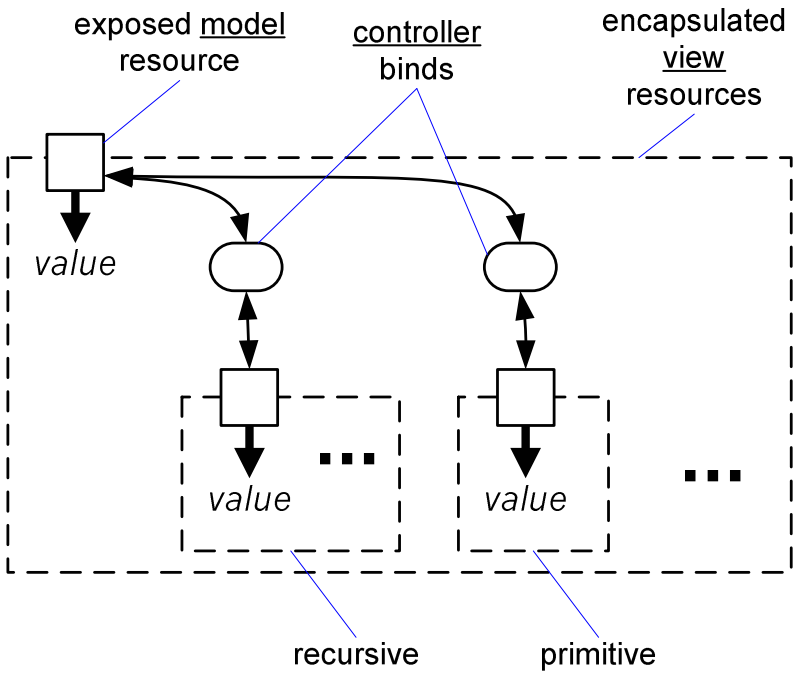
```
7 <c:bind>
    <c:in path="get-trigger"/>
    <c:in variable="$t" path="selected/temp"/>
    <c:out path="temp-input">{$t * 9 div 5 + 32}</c:out>
  </c:bind>

6 <c:bind>
    <c:in path="set-trigger"/>
    <c:in path="temp-input" variable="$t" passive="true"/>
    <c:out path="selected/temp">{($t - 32) * 5 div 9}</c:out>
  </c:bind>
```

- A form (1) represented by WEATHERMAN resource allows querying and updating a relational database (2) of weather information
- The <create> construct associates UI elements such as inputs (3) and triggers (4) with the WEATHERMAN class
- The <let> construct (5) uses the "city" input field to select a row from the database, recording it using the "selected" property
- The <bind> construct (6), triggered by the "set" trigger (4), updates the database with the quantity in the "temperature" input field, after converting Fahrenheit to Celsius
- A similar <bind> construct (7) retrieves the temperature from the database, converting Celsius to Fahrenheit.
- Dashed boxes indicate possible distribution scenario

demo/weather.xml

INTERACTION AND COMPOSITION

Recursive MVC

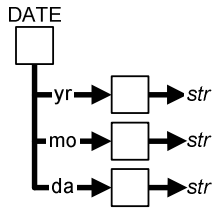


Collage generalizes recursive MVC as a key composition mechanism

- MVC
  - model: resource with a value
  - view: set of associated resources
  - controller: binds connecting model with view
- Recursive
  - view resources may be models to further views
  - turtles all the way down: recursion is grounded in primitive resource classes representing primitive units of interaction
- Abstraction defined by
  - model content
  - model behavior
- Refinement
  - view refines (possibly implements) model abstraction
- Encapsulation
  - model is exposed
  - model encapsulates view
- Data as interface
  - permissible and observed updates to model resource define interface to view

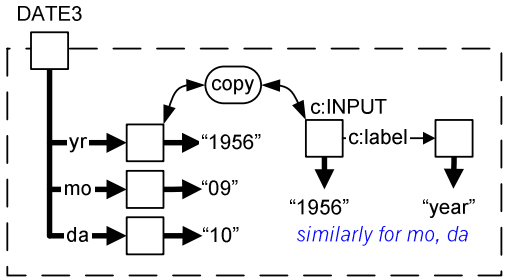
Flexible Decomposition and Styling Example

```
<c:with anchor="DATE">
   <c:create-structure>
      <yr/>
      <mo/>
      <da/>
   </c:create-structure>
</c:with>
```



- Define a DATE data structure: every resource of class DATE has associated yr, mo, and day resources as its value

```
<c:with anchor="DATE3">
   <c:create-view class="c:INPUT" ref="yr">
      <c:out path="c:label">year</c:out>
   </c:create-view>
   <c:create-view class="c:INPUT" ref="mo">
      <c:out path="c:label">month</c:out>
   </c:create-view>
   <c:create-view class="c:INPUT" ref="da">
      <c:out path="c:label">day</c:out>
   </c:create-view>
</c:with>
```

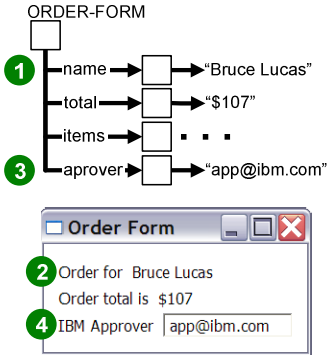


- Define a DATE3 view that associates three input fields with any data structure that has yr, mo, da resources

```
<c:let anchor="DATE" class="DATE3"/>
```

- Style a DATE with a DATE3 view by classifying a DATE resource as DATE3.
- Here every DATE is a DATE3, but DATE3 classification might be applied selectively
- More flexible than subclassing:
  - DATE3 requires only yr, mo, da fields be present
  - DATE3 classification need not be applied at point of instantiation of resource

Open Composition and Adaptation Example



Bookseller Code

```
<c:with anchor="ORDER-FORM">

  define structure of model
1 <c:create-structure>
    <name/>
    <total/>
    <items/>
  </c:create-structure>

  display the customer name
2 <c:create-view class="c:OUTPUT" ref="name">
    <c:out path="c:label">Order for</c:out>
  </c:create-view>
  . . .
</c:with>
```

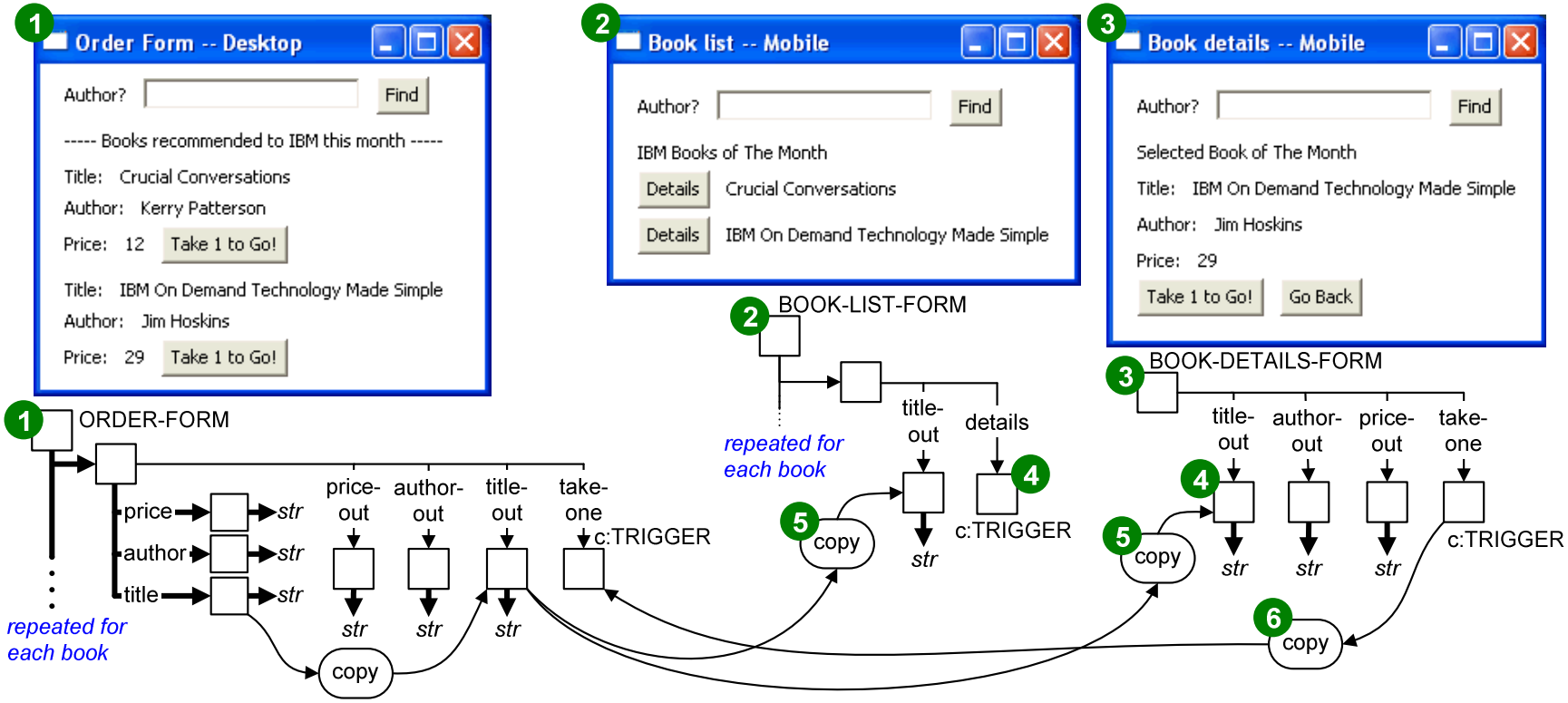
IBM Code

```
<c:with anchor="ORDER-FORM">

  define structure of model
3 <c:create-structure>
    <approver>app@ibm.com</approver>
  </c:create-structure>

  display the approver field
4 <c:create-view class="c:OUTPUT" ref="approver">
    <c:out path="c:label">IBM Approver</c:out>
  </c:create-view>

</c:with>
```

- Scenario: IBM partners with Bookseller to provide IBM employees with supplies
  - requires that IBM be able to modify "stock" Bookseller user interfaces and processes
- Bookseller defines stock
  - definition of the order form model (1)
  - order form presentation (2).
- IBM separately authors code to customize Bookseller form, specifying
  - the addition of an approver field to the model (3)
  - addition of a corresponding presentation item (4).
- <with> construct is comparable to class definition, but more flexible
  - complete definition of a class may be composed from multiple independently specified sources.
  - supports flexible multi-organizational composition of applications.

demo/bn demo/bn+ibm

Device Adaptation Example



- View (1) is search page from desktop book-ordering application
- Views (2) and (3) adapt view (1) to smaller screen of mobile device
- Use recursive MVC: view resources of (1) become model resources of (2) and (3)
- Adaptation accomplished by creating
  - new view elements (4),
  - binds linking the new view to the old (5)
  - binds controlling navigation (6).

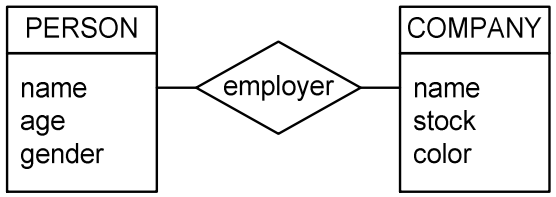
BACKUP

Relationship to XForms

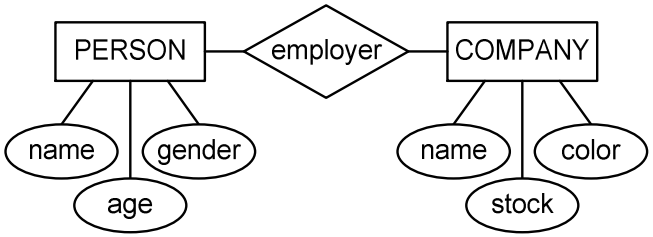
- Collage assumes RDF as a uniform underlying data model
  - simplifies programming model
  - eases evolution and refactoring by eliminating boundaries
- Collage leverages and extends concepts familiar from XForms
  - resource-resource bind unifies and generalizes model-view and model-model binds
  - declarative resource instantiation generalizes model-driven view instantiation
  - update-driven execution model regularizes the event model
  - uniform programming model across all application tiers
  - recursively composable

ER/UML Data Model Example

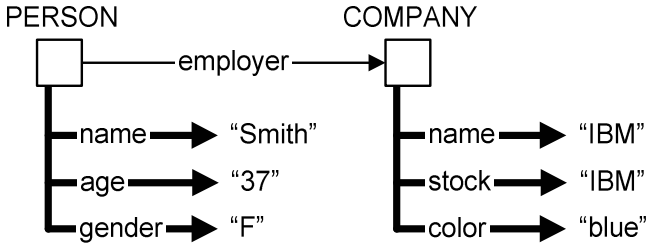
UML Diagram



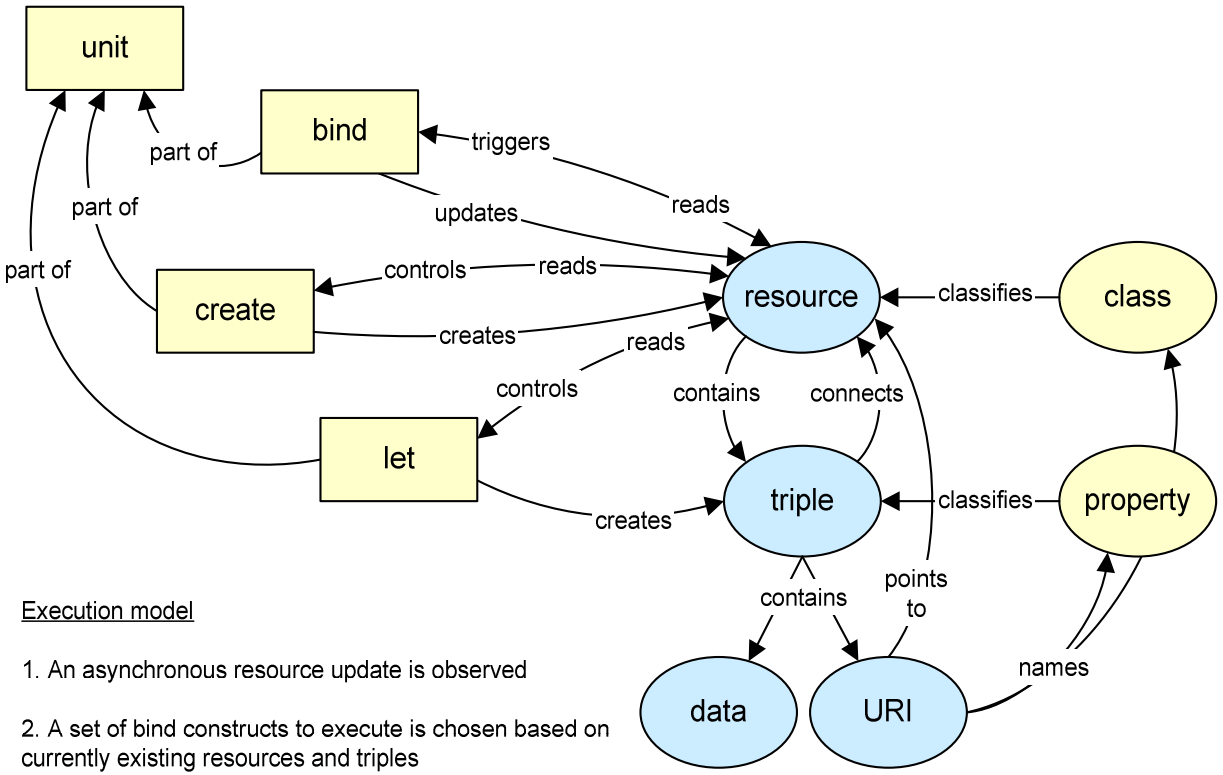
ER Diagram



Example RDF Instance



Collage Conceptual Summary



Execution model

1. An asynchronous resource update is observed

2. A set of bind constructs to execute is chosen based on currently existing resources and triples

3. The binds are executed in dependency order

4. Repeat/use and let constructs are executed based on updated resources to create new resources and triples