Towards a Repository of Common Programming Technologies Knowledge

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http://www4.in.tum.de/~ratiu/knowledge_repository.html

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Situation Today

- Reverse engineering is a knowledge intensive activity
  - To analyze programs, engineers need and use of a lot of knowledge about
    - Application domain
    - Software technologies
    - ... and how are they combined at the code level

but ...

Today's automatic tool support does not use this knowledge

because ...

There are currently no knowledge bases in a machine processable form, big enough and at the abstraction level of the source code

Situation Today (2)

- Ontologies are the de-facto technology for knowledge sharing
  - A lot of research efforts in the semantic web
- However, a search for suitable ontologies for analyzing programs (e.g. Swoogle) is disappointing because:
  - The existing ontologies do not cover the programming technologies domain
    - Or cover only small parts thereof
  - The concepts are not at the proper abstraction level that would enable automatic code analyses
- **Repository of ontologies about programming technologies knowledge**

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The Technologies Knowledge Repository

http://www4.in.tum.de/~ratiu/knowledge_repository.html

- Contains common sense, basic knowledge that is known by every programmer, e.g.
  - Dialogs are graphical widgets,
  - ... have titles, layout information,
  - ... can contain other graphical components
  - ... can be opened, closed, moved
  - ...

Usage Scenarios

- **Concept location**
  - We need semantics for the concepts
  - We need a conceptual (as opposed to structural) decomposition of the program

- **Assessing the quality of APIs**
  - In what measure does an API cover its domain?
  - How extensible is an API with respect to its domain?
  - How faithful does the API implement the domain?
  - How domain appropriate is an API?

Usage Scenarios (2)

- **Enriching program analyses with semantic information**
  - Clone detection vs. detecting logical redundancies
    - Multiple implementation of concepts in the code
  - Design quality assessment vs. appropriateness of the decomposition
    - A program abstraction implements different and unrelated domain concepts
      - e.g. logical GodClass
      - e.g. the persistency layer contains GUI concepts

- **Indexing reusable components**
  - Map the components (APIs) to the domain concepts that they implement
  - Search for suitable components in an automatic manner

Usage Scenarios (3)

- **Teaching and technology transfer**
  - Which concepts represent the core of the domain?
    - e.g. what are the most important GUI concepts?
  - Defining a common technological vocabulary in projects

- **Semantically rich IDE support**
  - Smart IDEs can look over the shoulder of programmers and give hints about the logical mistakes
    - Conceptual type checking
    - Enable active reuse – warn if a concept is already implemented

Usage Scenarios ...

The **possible applications** of the ontologies repository **are NOT limited** to the ones enumerated above.

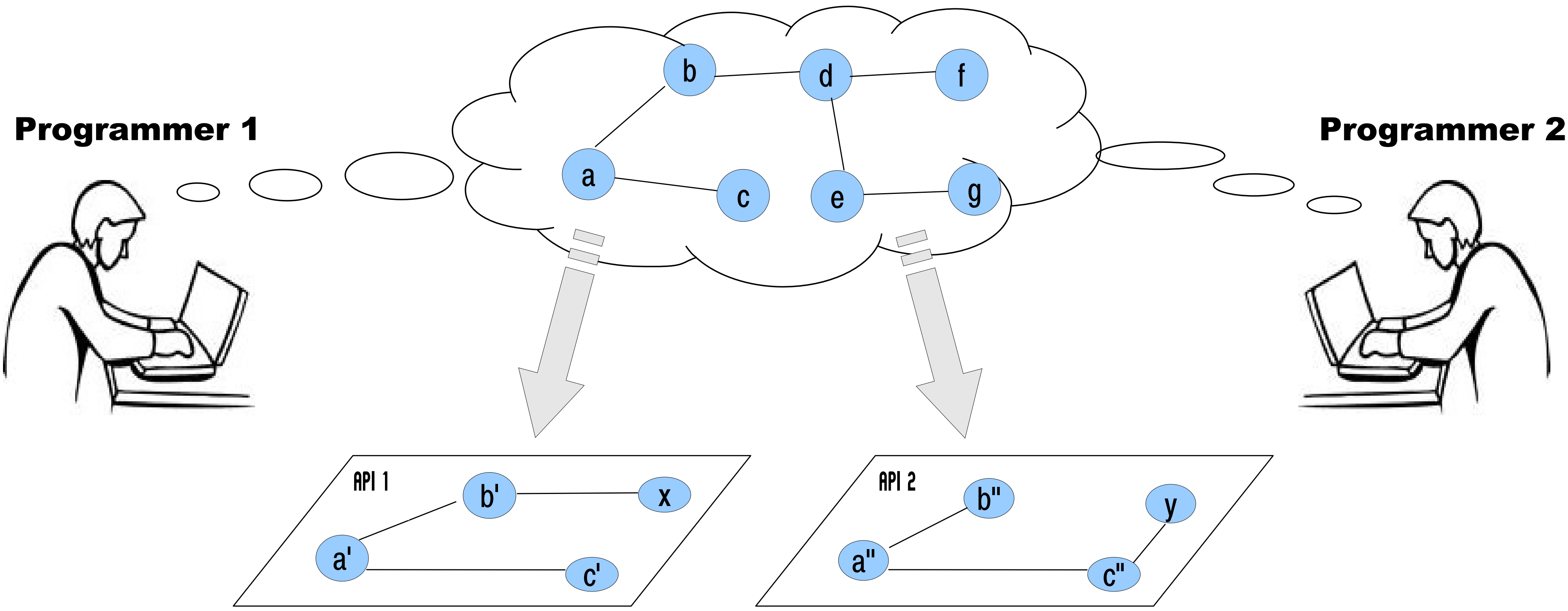
Once a **critical mass of knowledge** is available in machine processable form, it **will enable the development of semantic-aware program analysis tools**.

Our approach for building the ontologies

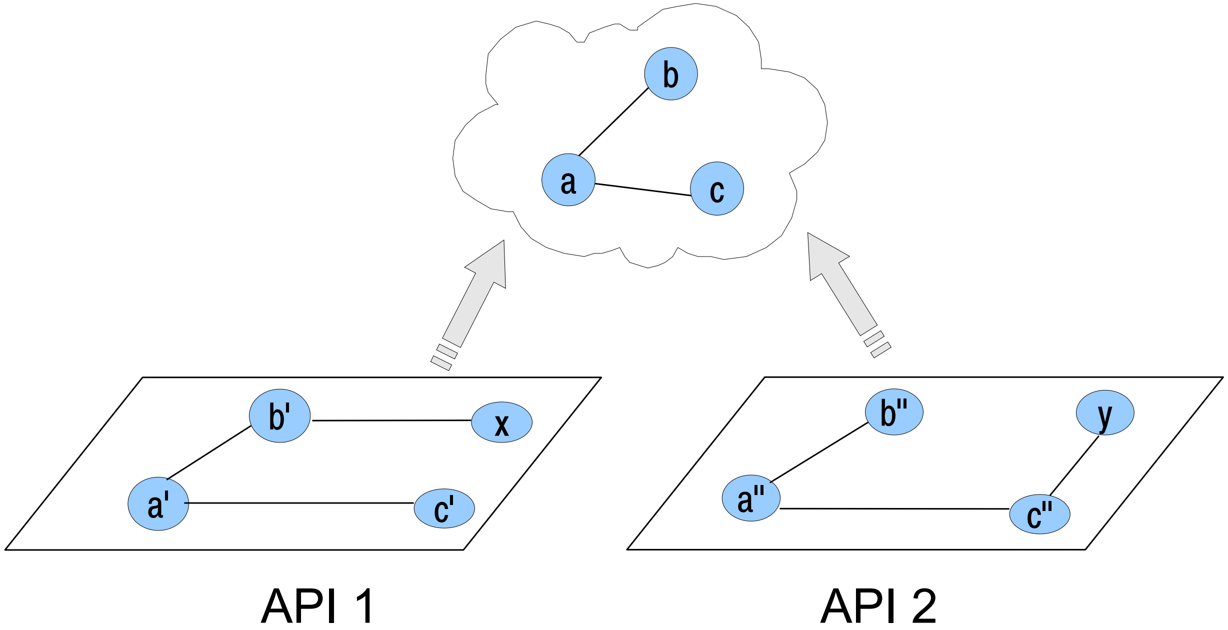
- Existing **APIs contain** an important amount of **knowledge about the programming technologies** at the abstraction level of programs
  - Every programming language provide its own implementation for GUIs, XML processing, data bases, networking, ...

- We mine the existing APIs in order to extract domain ontologies that
  - are at the abstraction level of the code
  - represent a consensus in a community
    - the APIs represent a de-facto vocabulary among programmers
  - are already used and shared by millions of programmers

Different APIs offer different Views over the Domain

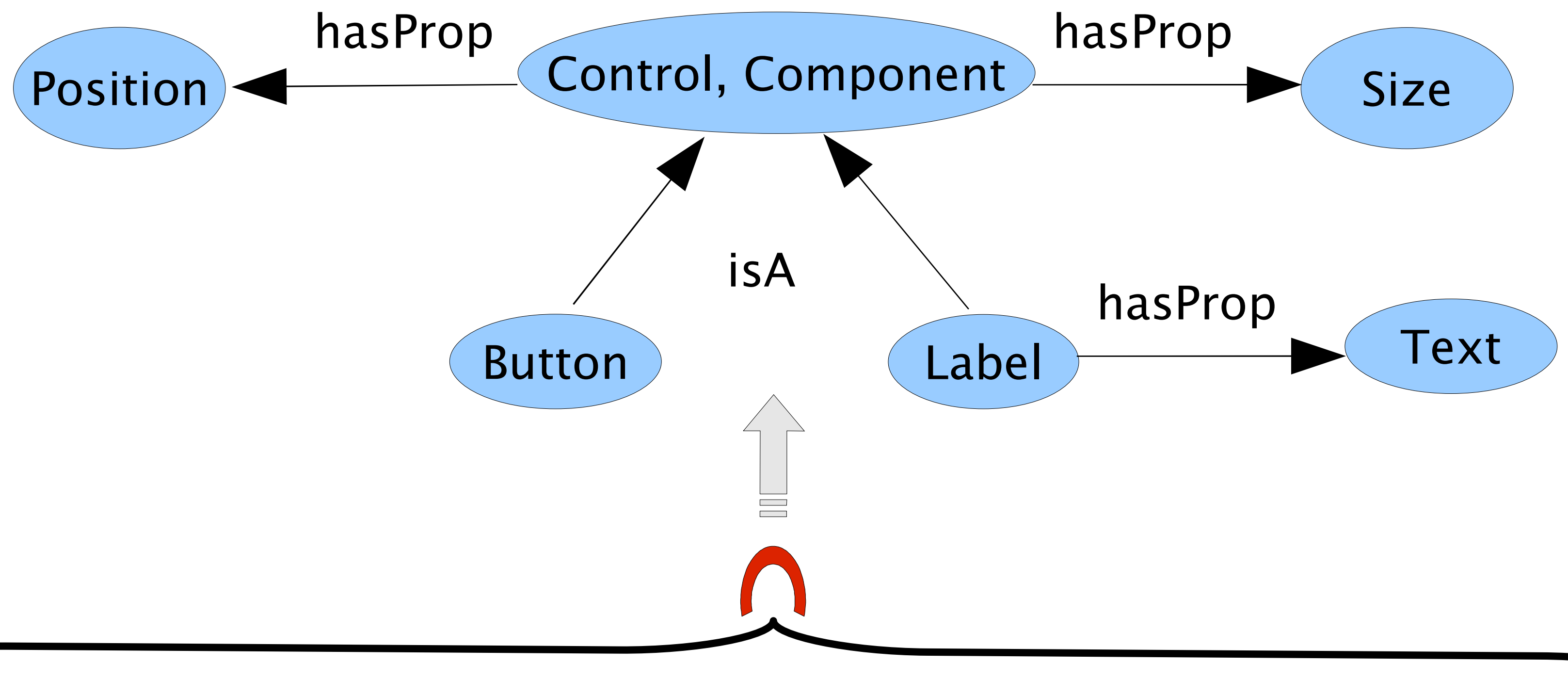


... but the **domain** is the same



... by exploiting the similarities between the APIs

Example



Java AWT

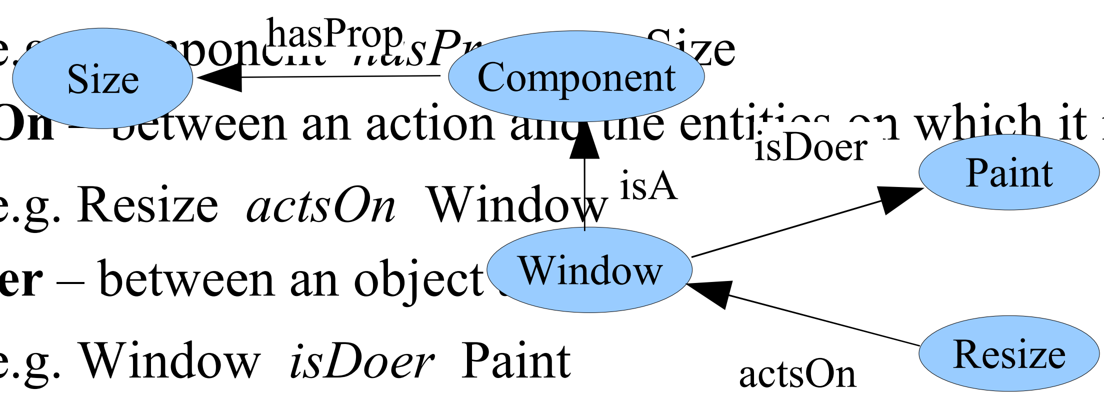
```
package java.awt;
class Component extends Object {
  int getSize() { … }
  int getLocation() { … }
}
class Button extends Component { … }
class Label extends Component {
  String getText() { … }
}
```

.Net Windows Forms

```
namespace  Windows.Forms;
class Control  :  … {
  public Point Location { get; set; }
  public Size Size { get; set; }
  public string Text { get; set; }
}
class Label  :  Control  { … }
class ButtonBase  :  Control  { … }
```

Describing Domain Knowledge with Ontologies

- Describe the domain as light-weighted ontologies represented as graphs (set of triples: subject – verb - object):
  - Nodes – domain concepts
  - Edges – relations between the concepts
    - **isA** - between subordinate and superordinate
      - e.g. Window *isA* Component
    - **hasProperty** – between a concept and its properties
      - e.g. Component *hasProperty* Size
    - **actsOn** – between an action and the entities on which it is performed
      - e.g. Resize *actsOn* Window
    - **isDoer** – between an object
      - e.g. Window *isDoer* Paint

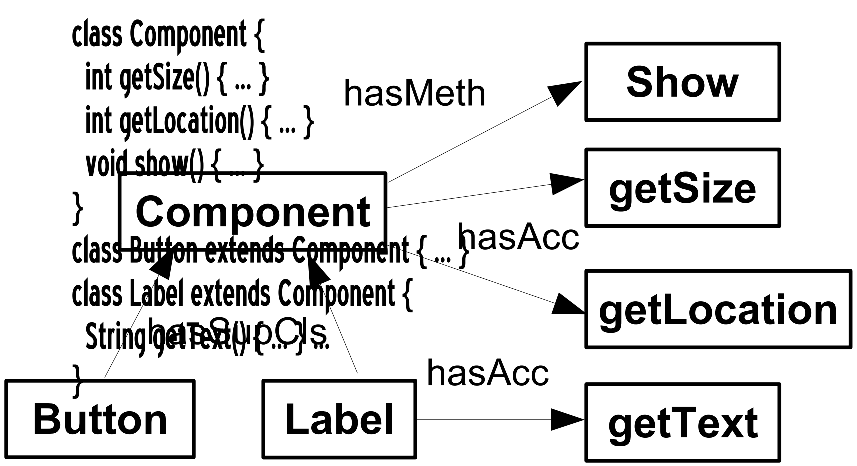


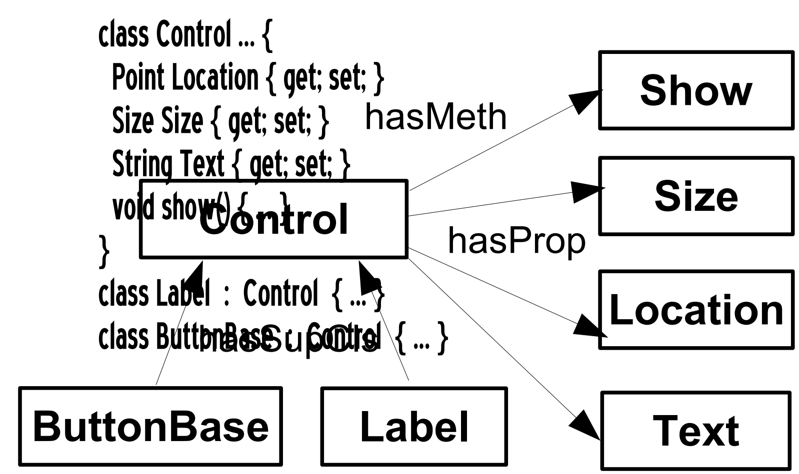
Extraction Steps

- **Step 1:** abstract the APIs in order to facilitate their comparison
- **Step 2:** inspect how are the abstract relations reflected in APIs
- **Step 3:** apply the ontology extraction algorithm
- **Step 4:** eliminate the noise

Step 1: Abstracting APIs

- We abstract APIs as graphs
  - Nodes = (lexically normalized) names of public program elements
  - Edges = program relations between the program elements
    - hasSupCls, hasAcc (Java), hasAtt, hasProp (C#), hasMeth, hasPar, hasType, hasConstr

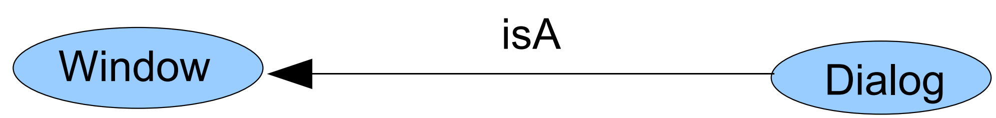




Step 2: Reflecting abstract relations in APIs

- The taxonomic relation (isA) is typically implemented as:
  - sub-classing (hasSupCls)
  - sequences of sub-classes (<hasSupCls, hasSupCls>)
  - the type of a variable (hasType)
- **Example:**

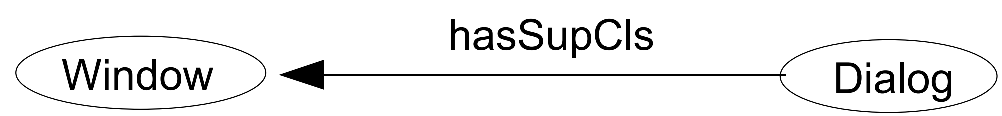
Dialog is a Window



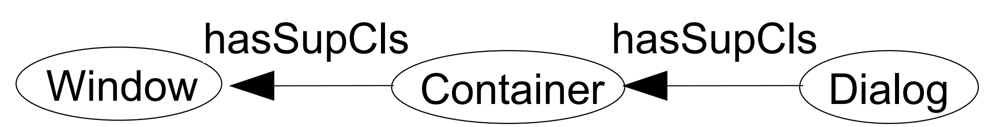
Ontology

APIs

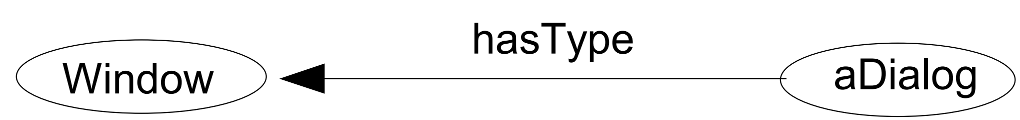
```
public class Window { ... }
public class Dialog extends Window {...}
```




```
public class Window { ... }
public class Container extends Window {...}
public class Dialog extends Container {...}
```




```
public class SomeClass {
  public Window aDialog; ...
}
```



Step 2: Reflecting abstract relations in APIs (2)

- The relation **“hasProperty”** between a concept and its properties is typically implemented as:
  - the attribute of a class (hasAtt)
  - the accessor of a class (hasAcc)
  - the parameter of a constructor (<hasConstr, hasPar>)
- **Example:**

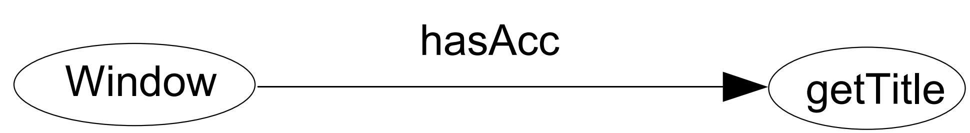
Window has Title

Ontology

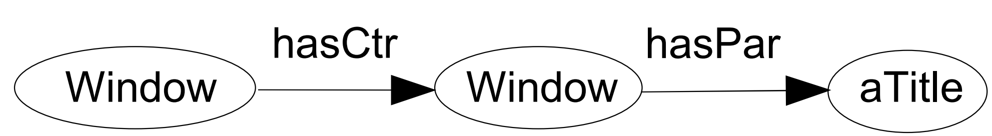
APIs

```
public class Window {
  public String title; ...
}
```


```
public class Window {
  public String getTitle() { ... }
}
```



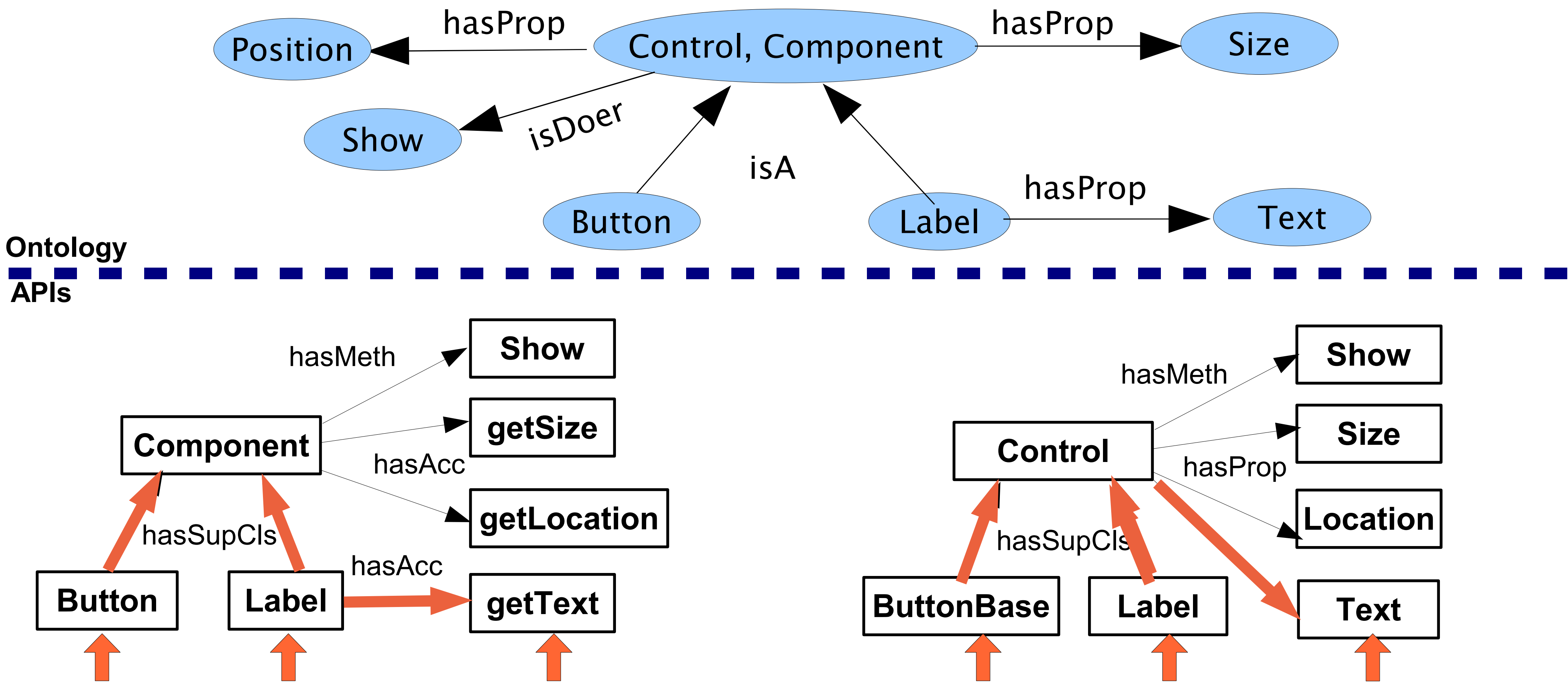

```
public class Window {
  public Window(String aTitle) { ... }
}
```



Step 3: Ontology extraction algorithm

- Extract the ontology as the intersection of the API graphs:
  - Matching nodes – based on the similarity of the names
  - Matching edges – according to the defined mapping strategies

At every step we discover a triple from our ontology



Example: GUI Concepts

- Accelerator
- Accessible
- Accessible Context
- Accessible Description
- Action
- Action Command
- Action Listener
- Activate
- Active
- Align
- Alignment
- Alignment X
- Alignment Y
- Button Border
- Alpha
- Angle
- Append
- Applet
- Arc
- Arc Angle
- Arc Height
- Arc Width
- Area
- Ascent
- Attribute
- Back
- Back Color
- Background
- Background Image
- Bar
- Bar Menu
- Base
- Baseline
- Bgcolor
- Block
- Blue
- Border
- Border Style
- Bottom
- Bound
- Box
- Browser
- Button

GUI Triples (1)

- Button | hasProperty | Active
- Button | hasProperty | Alignment
- Button | hasProperty | Background
- Button | hasProperty | Container
- Button | hasProperty | Content
- Button | hasProperty | Enable
- Button | hasProperty | Focus
- Button | hasProperty | Image
- Button | hasProperty | Label
- Button | hasProperty | Margin
- Button | hasProperty | Minimum Size
- Button | hasProperty | Mnemonic
- Button | hasProperty | Name
- Button | hasProperty | Parent
- Button | hasProperty | Style
- Button | hasProperty | Text
- Button | isA | Component
- Button | isA | Container
- Button | isA | Control
- Button | isA | Item
- Button | isA | Widget
- Button | isDoer | Check
- Button | isDoer | Click
- Button | isDoer | Focus
- Button | isDoer | Lost Focus
- Button | isDoer | Mouse Drag
- Button | isDoer | Mouse Move
- Button | isDoer | Notify

GUI Triples (2)

- Font | hasProperty | Bound
- Font | hasProperty | Family
- Font | hasProperty | Handle
- Font | hasProperty | Name
- Font | hasProperty | Size
- Font | hasProperty | Style
- Font | isA | Attribute
- Font | isA | Resource
- Font | isA | Text

The Knowledge Repository

- **Contributors:**
  - Martin Feilkas (.Net)
  - Adrian Linhard (Smalltalk)
  - Petru Mihancea (C++)
  - Yongming Li
  - Daniel Ratiu (Java)
- **Available ontologies**
  - **GUI --** > 450 Concepts, > 1400 Relations
  - **XML --** > 150 Concepts, > 300 Relations
  - **Collections --** 46 Concepts, 62 Relations
  - **Calendar --** 46 Concepts, 46 Relations
- **License:** LGPL

http://www4.in.tum.de/~ratiu/knowledge_repository.html

Scaling-up with Semantic Technologies

- Extracting (parts of) an ontology from analyzing more domain specific APIs is only the first step, in the practice there are several **pressing issues** like:
  - Obtaining richer ontologies
    - More kinds of relations, more semantic (constraints)
  - Validating and manually completing the ontology
    - Correctness and completeness
  - Evolving the extracted ontology
    - Analyze new APIs, consistently merge new concepts
  - Manipulating big ontologies

We build a community for the technologies repository

- **Users**
  - **use the ontologies in your research / tools**
- **Contributors**
  - **enhance the repository**

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