

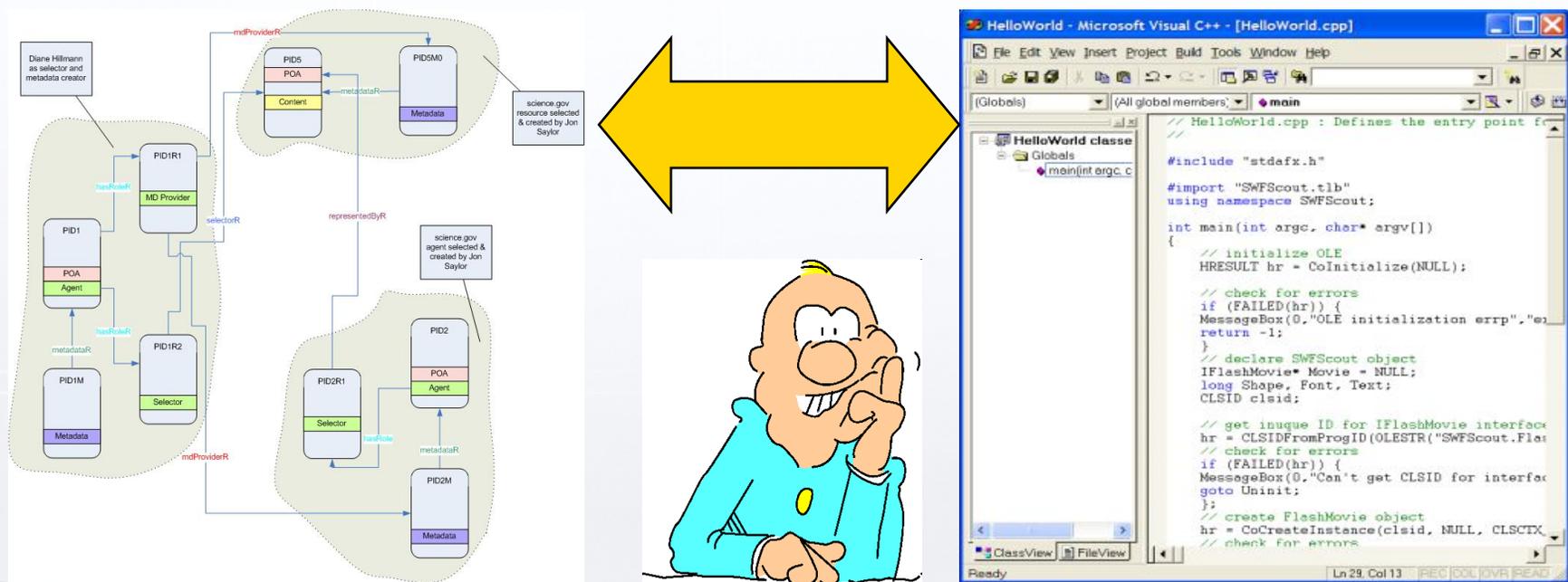


Enhancing Software Traceability By Automatically Expanding Corpora With Relevant Documentation

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Requirements Traceability (RT)

- Mapping requirements to software artifacts
 - Requirements are expressed using text, diagrams, or schemas
 - Software artifacts include code, configuration data, and databases
- Requirements traceability leads to better code understanding



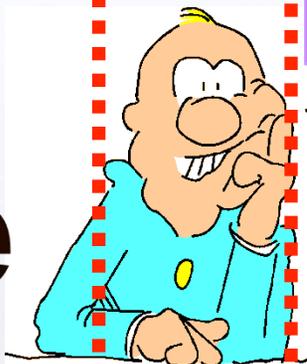
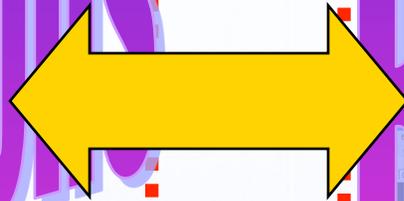
Tracing Requirements

locate

search

Abstractions

secure



Realizations

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1 //  
2 * Copyright 2006 Accenture, LLP. All rights reserved.  
3 * Accenture Proprietary/Confidential.  
4  
5 Reviewed:  
6 - Never  
7  
8 package com.accenture.techlabs.stiletto.designer;  
9  
10 import java.io.InputStream;  
11  
12 /**  
13  *  
14  * TODO Description of GuiElementTypesIcons.  
15  * Author <a href="mailto:kevin.m.conroy@accenture.com">Kevin M. Conroy</a>  
16  * Version 1.0  
17  */  
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22  
23 public class GuiElementTypesIcons {  
24     /**  
25      * TODO Describes field ICONS_DIR.  
26      */  
27     private static final String ICONS_DIR = "/com/  
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Traceability Links

locate

service

send

XML

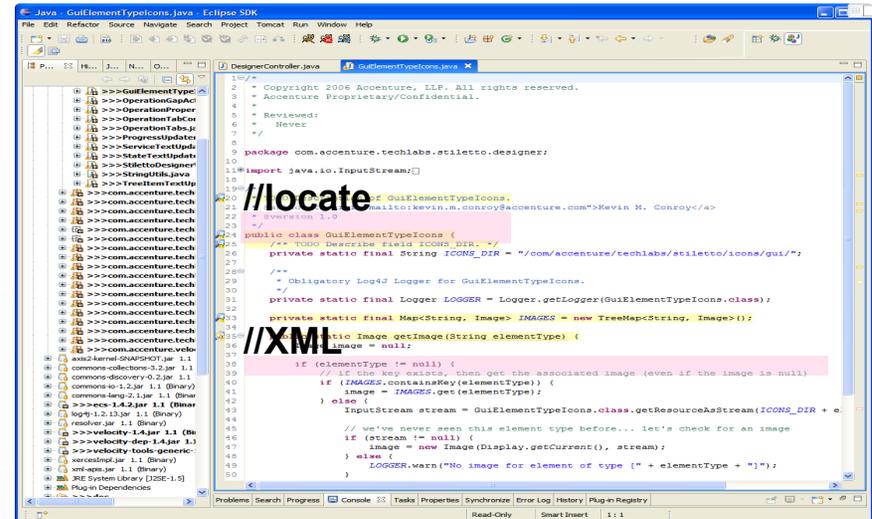
secure

```
1 //
2 * Copyright 2006 Accenture, LLP. All rights reserved.
3 * Accenture Proprietary/Confidential.
4 * Reviewed:
5 * Never
6 **
7 package com.accenture.techlabs.stiletto.designer;
8
9 import java.io.InputStream;
10
11 /**
12  * TODO Description of GuiElementTypeIcons.
13  * Author <a href="mailto:kevin.m.conroy@accenture.com">Kevin M. Conroy</a>
14  * Version 1.0
15  */
16 public class GuiElementTypeIcons {
17     private static final String ICONS_DIR = "/com/accenture/techlabs/stiletto/icons/gui/";
18     //
19     // Obligatory Log4J Logger for GuiElementTypeIcons.
20     private static final Logger LOGGER = Logger.getLogger(GuiElementTypeIcons.class);
21     private static final Map<String, Image> IMAGES = new TreeMap<String, Image>();
22     public static Image getImage(String elementType) {
23         Image image = null;
24         if (elementType != null) {
25             // If the key exists, then get the associated image (even if the image is null)
26             if (IMAGES.containsKey(elementType)) {
27                 image = IMAGES.get(elementType);
28             } else {
29                 InputStream stream = GuiElementTypeIcons.class.getResourceAsStream(ICONS_DIR + e
30                 // We've never seen this element type before... let's check for an image
31                 if (stream != null) {
32                     image = new Image(Display.getCurrent(), stream);
33                 } else {
34                     LOGGER.warn("No image for element of type [" + elementType + "]");
35                 }
36             }
37         }
38     }
39 }
```

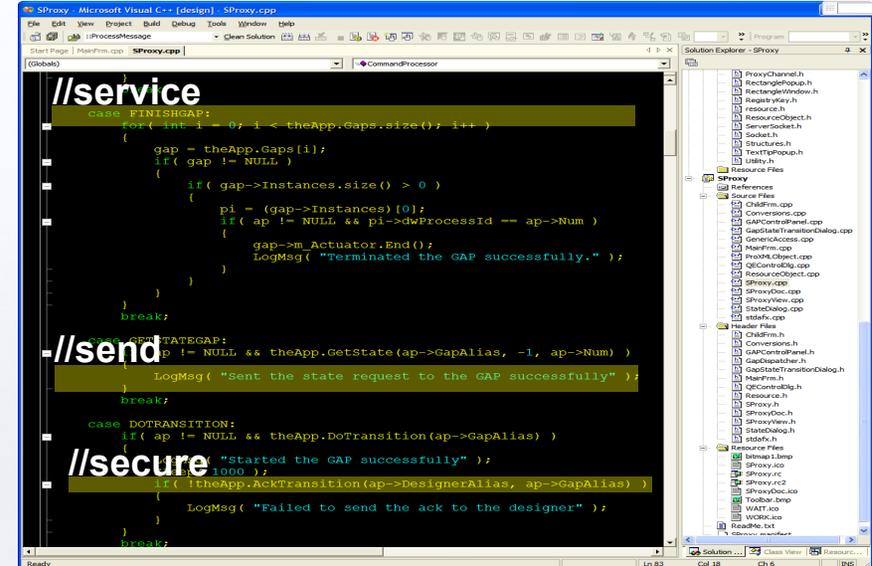
```
case FINISHGAP:
    for ( int i = 0; i < theApp.Gaps.size(); i++ )
    {
        gap = theApp.Gaps[i];
        if ( gap != NULL )
        {
            if ( gap->Instances.size() > 0 )
            {
                pi = (gap->Instances)[0];
                if ( ap != NULL && pi->dwProcessId == ap->Num )
                {
                    gap->m_Actuator.End();
                    LogMsg( "Terminated the GAP successfully." );
                }
            }
            break;
        }
    }
case GETSTATEGAP:
    if ( ap != NULL && theApp.GetState(ap->GapAlias, -1, ap->Num ) )
    {
        LogMsg( "Sent the state request to the GAP successfully" );
    }
    break;
case DOTRANSITION:
    if ( ap != NULL && theApp.DoTransition(ap->GapAlias ) )
    {
        LogMsg( "Started the GAP successfully" );
        Sleep( 1000 );
        if ( !theApp.AckTransition(ap->DesignerAlias, ap->GapAlias ) )
        {
            LogMsg( "Failed to send the ack to the designer" );
        }
    }
    break;
}
```

Traceability Links (TLs)

- TLs are mappings between concepts in high-level requirements and design documents and program entities
- TLs can be viewed as matches between words in requirements and code.

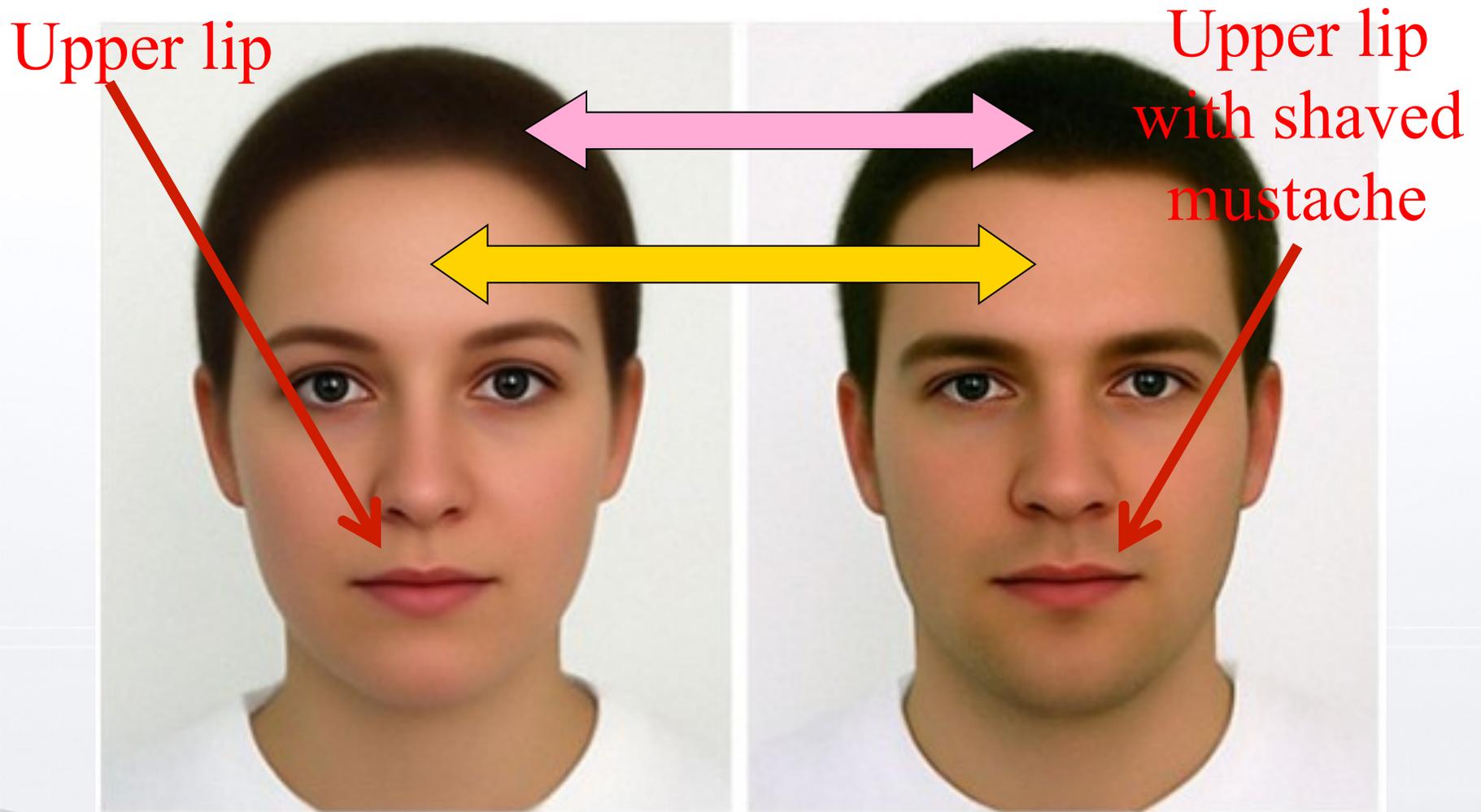


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1 //
2 * Copyright 2006 Accenture, LLP. All rights reserved.
3 * Accenture Proprietary/Confidential.
4
5 * Reviewed:
6 * Never
7
8 **
9
10
11 package com.accenture.techlabs.stiletto.designer;
12
13 import java.io.InputStream;
14
15 //locate
16 //Mailto:kevin.h.conroy@accenture.com*Kevin H. Conroy/>
17 * Version 1.0
18
19
20 public class GuiElementTypeIcons {
21     /** TODO Determine if is ICONS_DIR ??
22     private static final String ICONS_DIR = "/com/accenture/techlabs/stiletto/icons/gui/";
23
24     /**
25     * Obligatory Log4J Logger for GuiElementTypeIcons.
26     private static final Logger LOGGER = Logger.getLogger(GuiElementTypeIcons.class);
27
28     private static final Map<String, Image> IMAGES = new TreeMap<String, Image>();
29
30     public Image getImage(String elementType) {
31         Image = null;
32
33         if (elementType != null) {
34             // If the key exists, then get the associated image (even if the image is null)
35             if (IMAGES.containsKey(elementType)) {
36                 image = IMAGES.get(elementType);
37             } else {
38                 InputStream stream = GuiElementTypeIcons.class.getResourceAsStream(ICONS_DIR + e
39                 // We've never seen this element type before... let's check for an image
40                 if (stream != null) {
41                     image = new Image(Display.getCurrent(), stream);
42                 } else {
43                     LOGGER.warn("No image for element of type [" + elementType + "]);
44                 }
45             }
46         }
47     }
48 }
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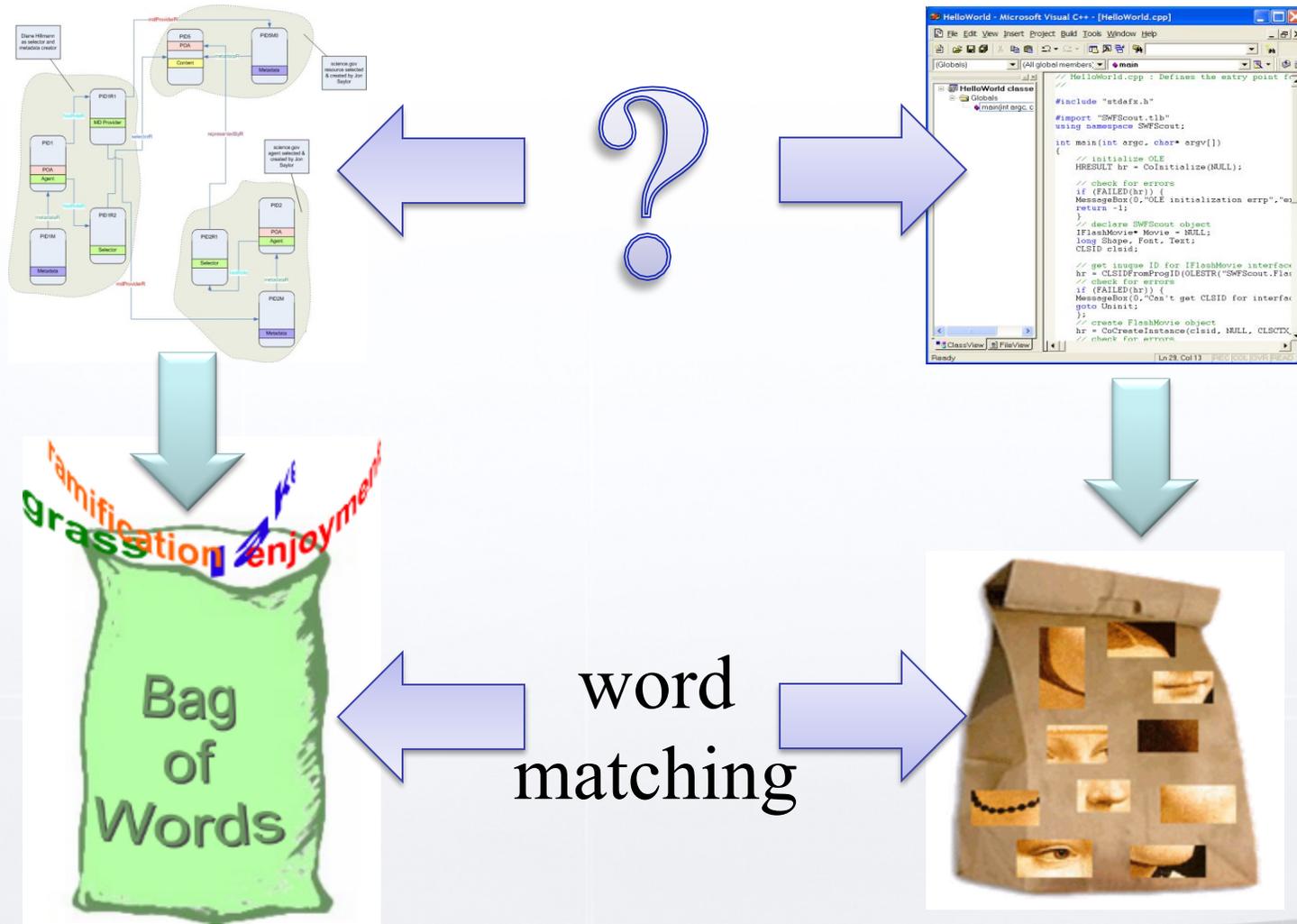


```
1 //service
2
3 case FINISHGAP:
4     for (int i = 0; i < theApp.Gaps.size(); i++)
5     {
6         gap = theApp.Gaps[i];
7         if (gap != NULL)
8         {
9             if (gap->Instances.size() > 0)
10            {
11                pi = (gap->Instances)[0];
12                if (ap != NULL && pi->dwProcessId == ap->Num)
13                {
14                    gap->m_Actuator.End();
15                    LogMsg("Terminated the GAP successfully.");
16                }
17            }
18            break;
19        }
20    }
21
22 //send
23 case DOTTRANSITION:
24     if (ap != NULL && theApp.GetState(ap->GapAlias, -1, ap->Num)
25     {
26         LogMsg("Sent the state request to the GAP successfully.");
27     }
28     break;
29
30 //secure
31 case DOTTRANSITION:
32     if (ap != NULL && theApp.DoTransition(ap->GapAlias)
33     {
34         LogMsg("Started the GAP successfully.");
35     }
36     if (!theApp.AckTransition(ap->DesignerAlias, ap->GapAlias)
37     {
38         LogMsg("Failed to send the ack to the designer.");
39     }
40     break;
41 }
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Traceability Is a Similarity Measure



Traceability Is a Similarity Measure



The Problem

Ouch!

Low precision of TLs

**Incorrect
TLs**

Vocabulary problem

**Missed
TLs**

Polysemy

**Lower
accuracy**

Synonymy

**It is a
norm**

Different stakeholders



**Software
quality is
affected**

Our Hypotheses

It is possible to increase the precision of information retrieval approaches that are based on syntagmatic associations

by expanding the vocabulary of artifacts using related words.

by using JDK API calls as semantic anchors.

by using the hybrid of syntagmatic and paradigmatic vocabulary expansions.

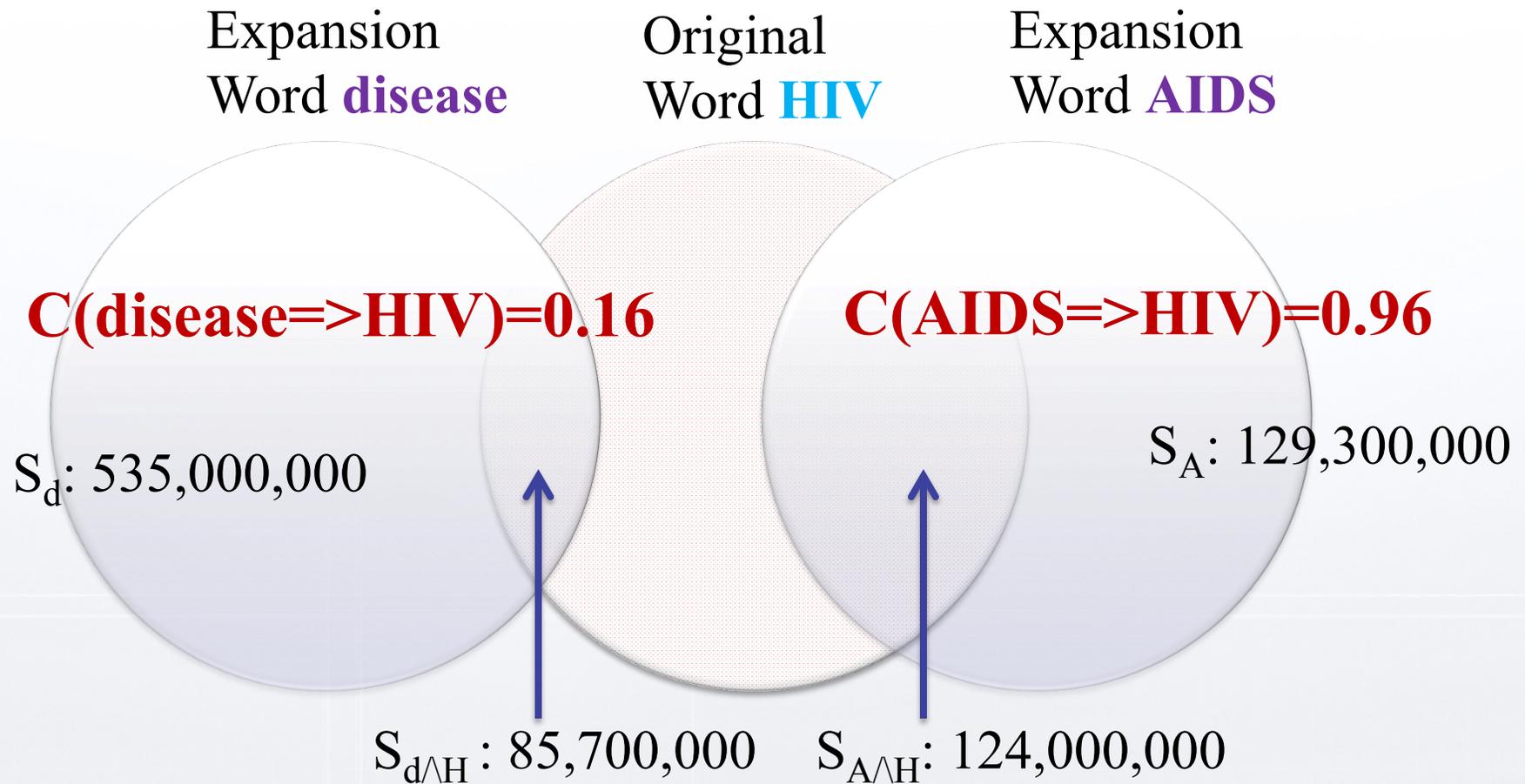


Key Question

How to expand the vocabulary automatically in a semantically meaningful and systematic way in order to increase the accuracy of automatic traceability approaches?



Expansion With Related Words



Expanding JDK API Calls

All Classes

Packages

java.applet
java.awt
java.awt.color
java.awt.datatransfer
java.awt.dnd
java.awt.event
java.awt.font
java.awt.geom
java.awt.im
java.awt.im.spi
java.awt.image
java.awt.image.renderable
PrinterName
PrinterResolution
PrinterState
PrinterStateReason
PrinterStateReasons
PrinterURI
PrintEvent
PrintException
PrintGraphics
PrintJob
PrintJobAdapter
PrintJobAttribute
PrintJobAttributeEvent
PrintJobAttributeListener
PrintJobAttributeSet
PrintJobEvent
PrintJobListener
PrintQuality
PrintRequestAttribute
PrintRequestAttributeSet
PrintService
PrintServiceAttribute
PrintServiceAttributeEvent
PrintServiceAttributeListener
PrintServiceAttributeSet
PrintServiceLookup
PrintStream
PrintWriter
PriorityBlockingQueue
PriorityQueue
PRIVATE_MEMBER
PrivateClassLoader
PrivateCredentialPermission
PrivateKey
PrivateMLet
PrivilegedAction
PrivilegedActionException

Method Detail

getStringTable

```
protected String[] getStringTable()
```

Returns the string table for class PrintQuality.

Overrides:

getStringTable in class EnumSyntax

Returns:

the string table

getEnumValueTable

```
protected EnumSyntax[] getEnumValueTable()
```

Returns the enumeration value table for class PrintQuality.

Overrides:

getEnumValueTable in class EnumSyntax

Returns:

the value table

getOffset

```
protected int getOffset()
```

Returns the lowest integer value used by class PrintQuality.

Overrides:

getOffset in class EnumSyntax

Returns:

the offset of the lowest enumeration value.

Experiments

We used TraceLab

- <http://www.coest.org>

We experimented with multiple IR approaches

- VSM, LSI, JS, LDA, RTM

Corpus Treatment Methods

Strawman

Our baseline method

- Complete source code corpus is treated as bag of words.

JDK expansion

Replaced JDK API calls with their corresponding description in the JDK documentation.

- Identifiers are split.
- Comments are discarded.

J+W

Extension of JDK expansion where

- Wordnet synsets of dictionary words found in the corpus are injected.

J+S

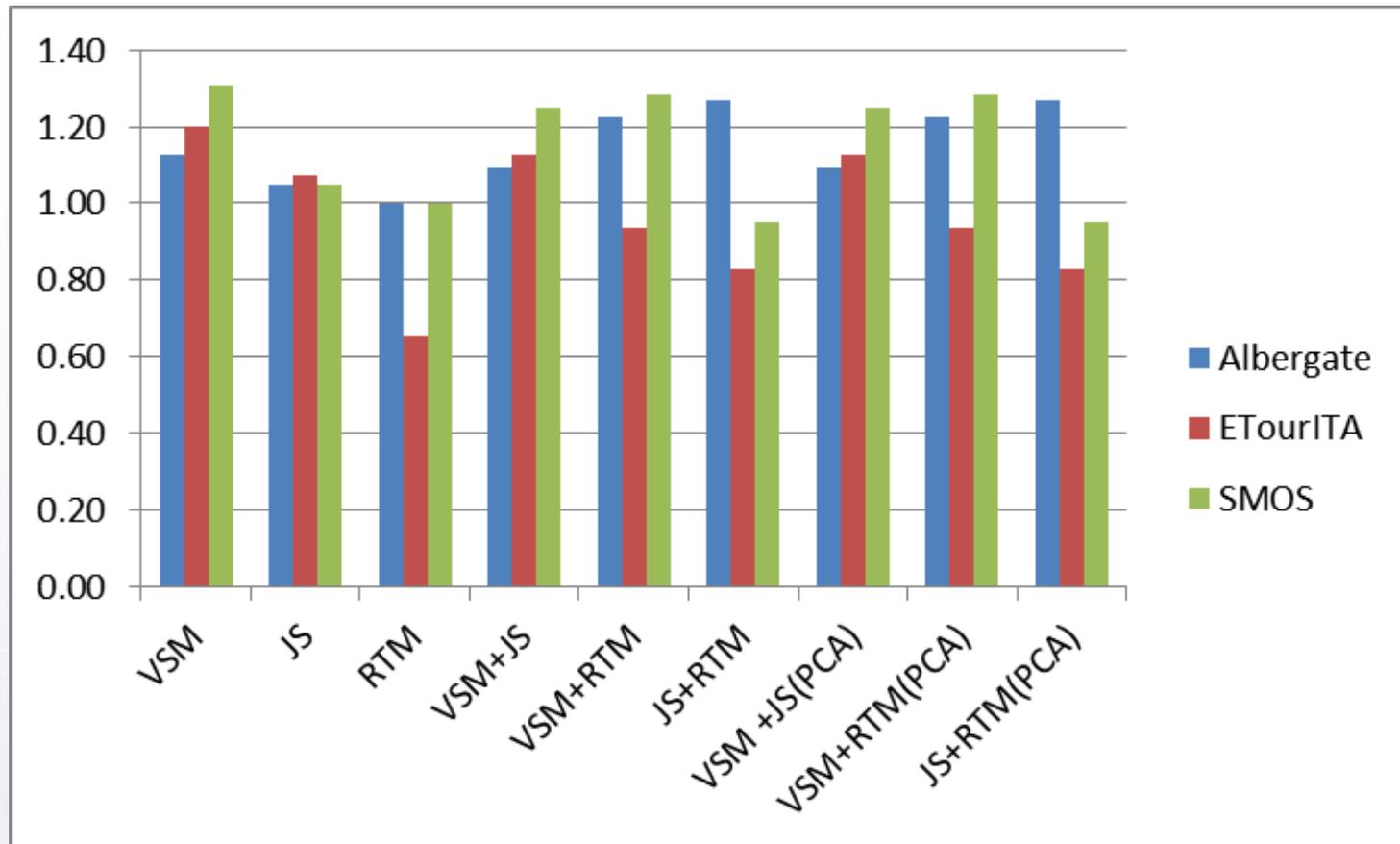
Expansion of S and JDK

- Comments are included.

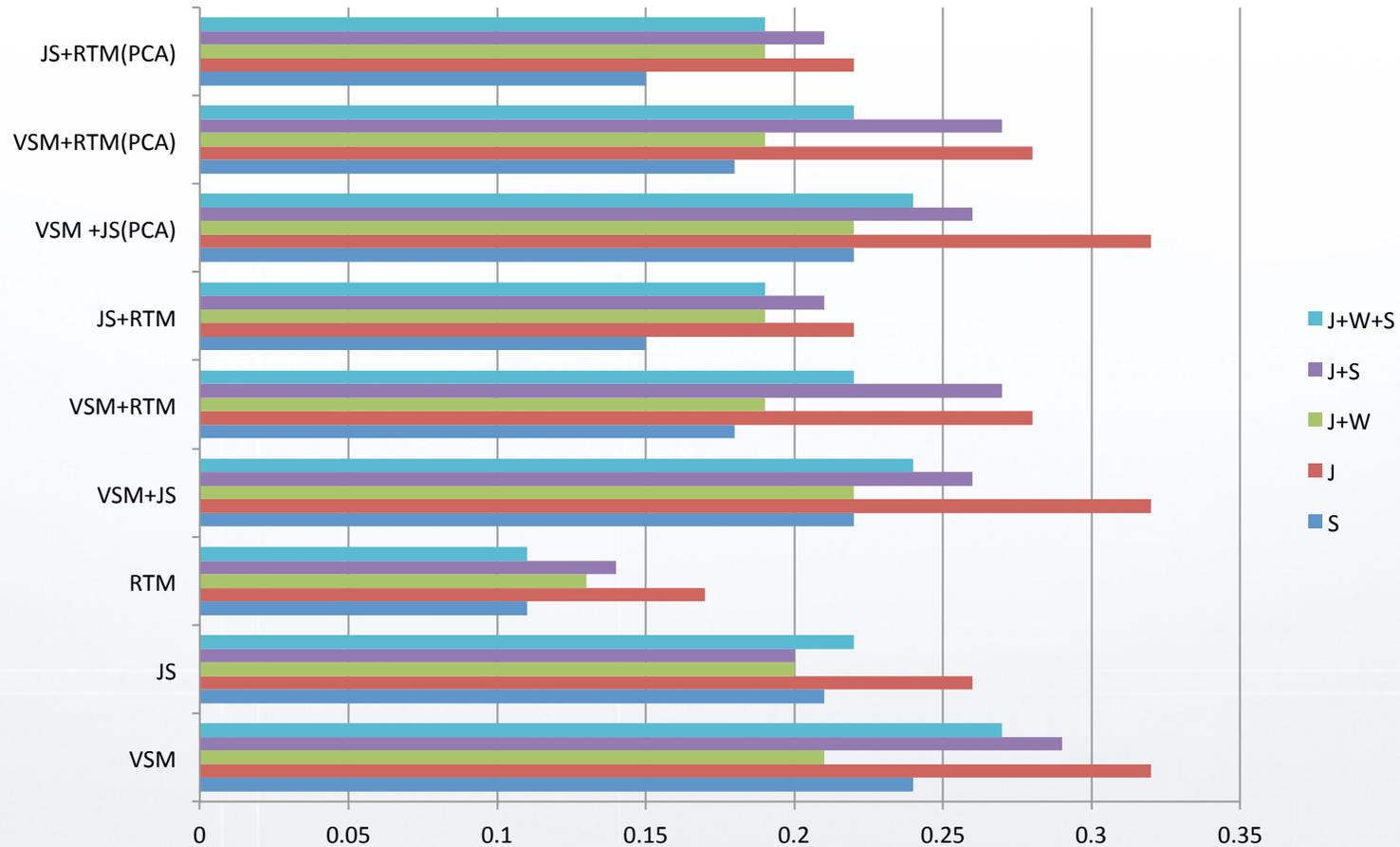
J+S+W

is ENTRANCER

Summary of Results



Summary of Results For Albergate



Results

RQ1

Expanding the corpus with the documentation JDK API calls only is often not enough to get higher precision of traceability links when applying word match similarity methods.

RQ2

expansion of the corpus with a combined documentation from the JDK API calls and Wordnet does not always result in a higher precision of traceability links

Results

RQ3

including words from comments results in a higher precision of traceability links when expanding the corpus with a combined documentation from the JDK API calls and Wordnet.

RQ4

There is a correlation between the size of the corpus and higher precision of recovered TLs.

RQ5

using VSM results in a higher precision of traceability links when expanding the corpus with a combined documentation from the JDK API calls and Wordnet

It Is Just the Tip of The Iceberg



We need systematic methods to expand the corpora to experiment with traceability and to increase the precision of different traceability approaches.

Conclusions

An automatic approach for ENhancing TRAcability usiNg API Calls and rElevant woRds (ENTRANCER).

This is the first comprehensive study of an automated approach that expands the base multilingual corpora, i.e., Italian and English.

We showed that ENTRANCER can increase the precision of the recovered TLs by up to 31% in the best case.



Thank You

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<http://www.cs.uic.edu/~drmark/entrancer.htm>

