

APPLICATION OF REINFORCEMENT LEARNING (RL) TECHNIQUES TO REQUIREMENTS TRACING



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2

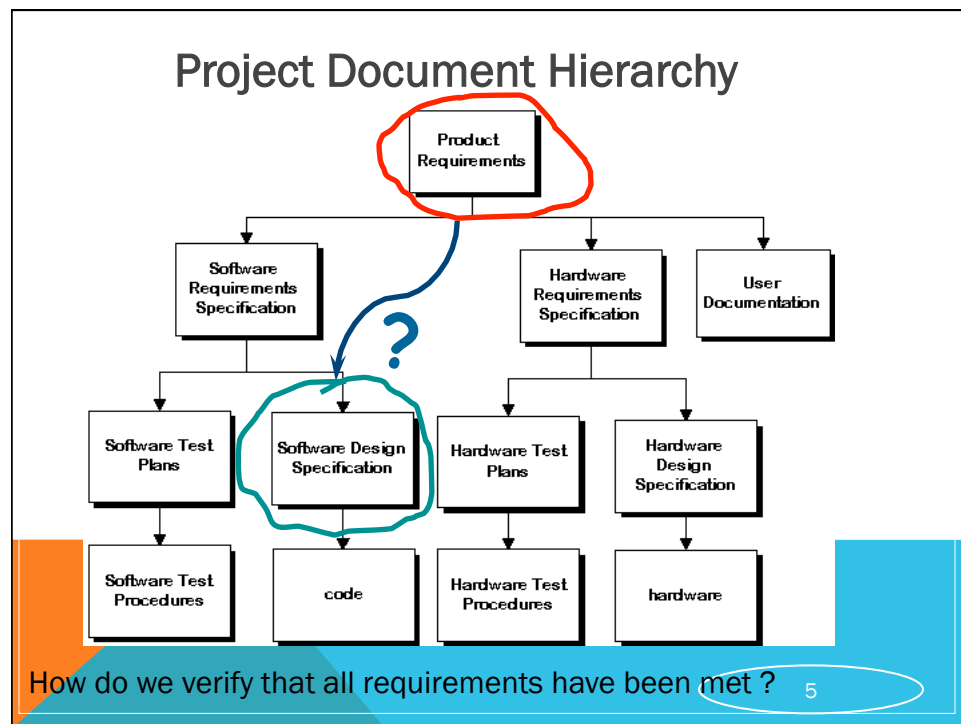
Outline

- Requirements tracing
- Biologically inspired computation
- RL for tracing
- Related work
- Validation
- Observations and conclusions

3

Requirements tracing – what, why?

What? – relationships between software artifacts at detailed level



Testing Center

Contents | Properties

Contents

New Add requirements

Beta Test Plan 2479: Add Items to Shopping Cart

1 Add an existing requirement to the test plan

Existing test cases linked to this requirement are displayed

Test suite: 247... (Requirement 2479)
Default configurations (1): Vista a... State: In progress

Open Add New Assign Configur...

Drag a column header here to group by that column.

ID	Title	Priority
2493	Add 100 items to shopping cart	2
2496	Add item to shopping cart	2

2

3 Create new test cases linked to this requirement

Sample Trace Matrix (TM)

	DE1	DE2	DE3	DE4
R1		X	X	X
R2	X			
R3		X		

Key: R1 – Requirement 1, DE1 – Design Element 1

Requirements (high level)

R1: The system shall provide a method for input and output.

R2: The system shall allow 3 users to log on simultaneously.

R3: There shall be a way to record output in XML format.

Design Elements (low level)

DE1: The trackUser semaphore allows up to 3 users to be signed on at any point.

DE2: An output file, out.xml, will be written using the XML format specified in STDDOC1.2.3.

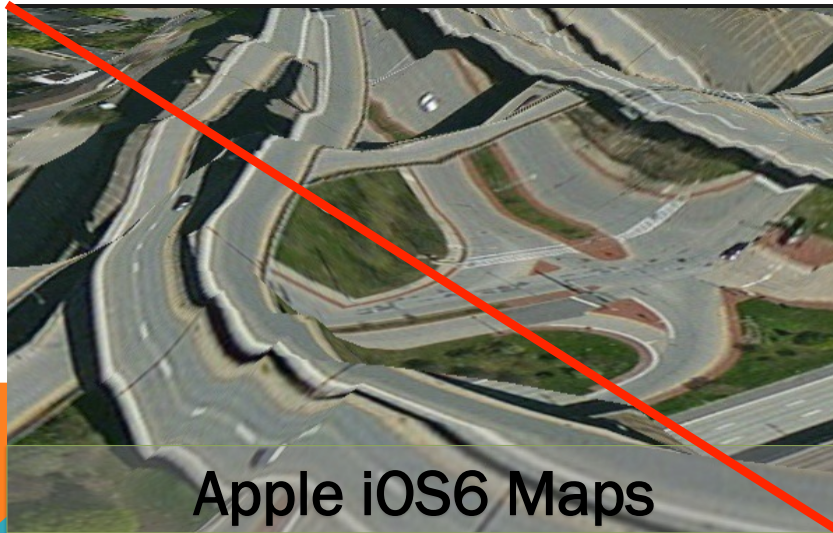
DE3: The system shall read user input in the format specified in STDDOC1.2.3.

DE4: User input may also be given manually through keyboard entry.

Requirements Tracing – What, Why?

- What? – relationships between software artifacts at detailed level
- Why? – development, V&V/IV&V, evolution, and more

Quality of Requirements



Apple iOS6 Maps



Requirements tracing – how?

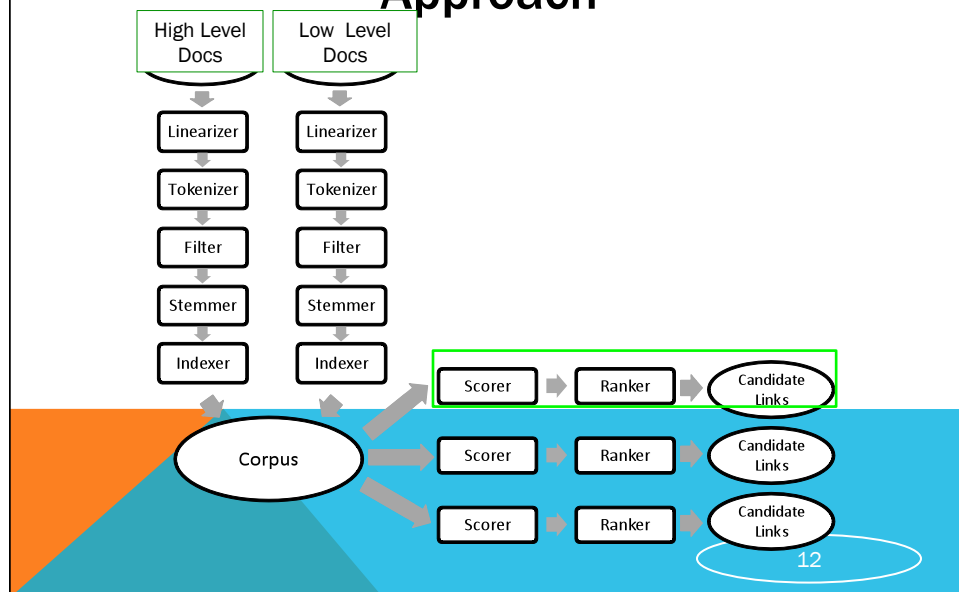
Some tools largely manual

Myriad of link generation methods

- Information retrieval-based
- Rule-based
- Soft goal interdependency graph-based

**Vector Space Model with term
frequency – inverse document
frequency weighting**

Typical Information Retrieval (IR) Approach



Evaluation of IR Approach

Candidate Link List Evaluation

HighDocs	LowDocs	Weight
SDP3.3-4	L1APR01-I-1	0.868215278
SDP3.3-4	L1APR01-F-2.2.3-4	0.102804641
SDP3.3-4	L1APR01-F-4-3	0.083900716
SDP3.3-4	L1APR01-F-2.1-4	0.081284136
SDP3.3-4	L1APR03-F-1-2	0.078608219
SDP3.3-4	L1APR03-I-5	0.06709611
SDP3.3-4	L1APR03-F-3.2.1-2	0.055489017
SDP3.3-4	L1APR01-F-2.2.4-2	0.055132765
SDP3.3-4	L1APR01-F-2.1-1	0.051063439
SDP4.2-2	L1APR01-F-4-3	0.649469866

Candidate Link List

13

Information Retrieval Measures

- Recall $R = TP / (FN + TP)$
- Precision $P = TP / (FP + TP)$ [13]

14

Issues with Vector Space Model

- Curse of dimensionality
- Precision/recall trade off
- Bag of words

15

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16



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Reinforcement Learning

RL model can be presented as $(S, A, \{P_{sa}\}, \gamma, R)$, [8]

S states

A actions

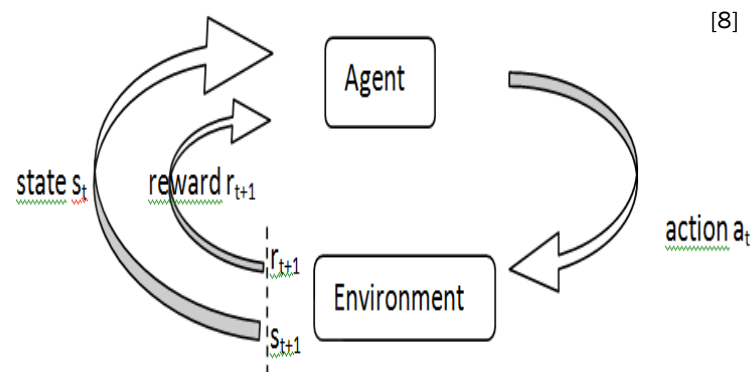
P probability

γ discount, $0 \leq \gamma \leq 1$

R reward

19

Reinforcement Learning



Artifacts as search space

“A9. The system shall have an address book available to store contacts. The address book shall store contacts in groups as well.”

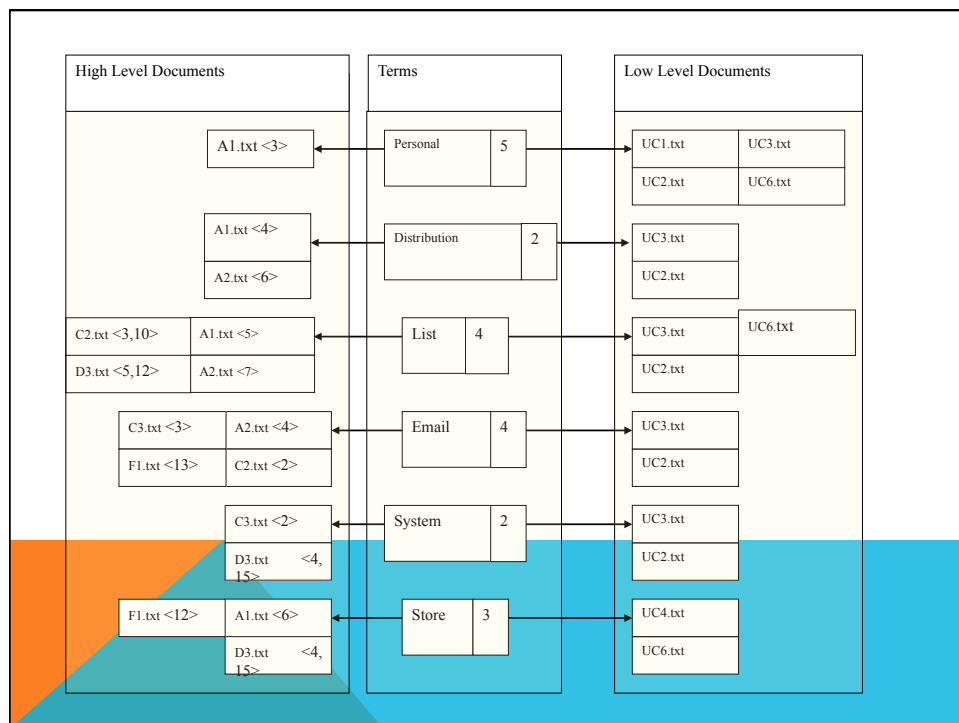
“C5. The system shall support a text-based interface to compose mail, use mail addresses from an address book, and attach mail stored in folders.”

“F6. The system shall support the ability for users to create a folder to store mail. The system shall support uploading mail that is stored in folders.”

“UC5. The system shall have an address book available to store contacts.”

“UC34. The system shall support a text-based interface to compose mail, use mail addresses from an address book, and attach mail stored in folders.”

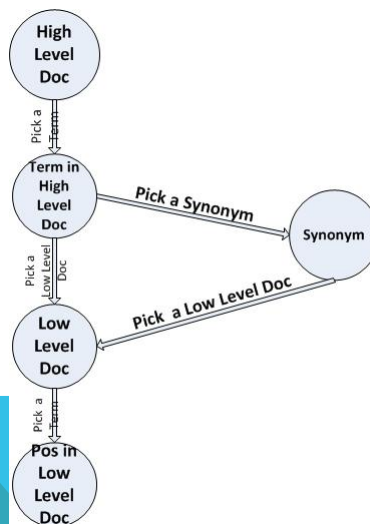
“UC2. The system shall support the ability for users to create a folder to store mail.”



Key features of RL approach

Agents
States
Actions
Reward
Neighborhood
Thesaurus

Reinforcement Learning



24

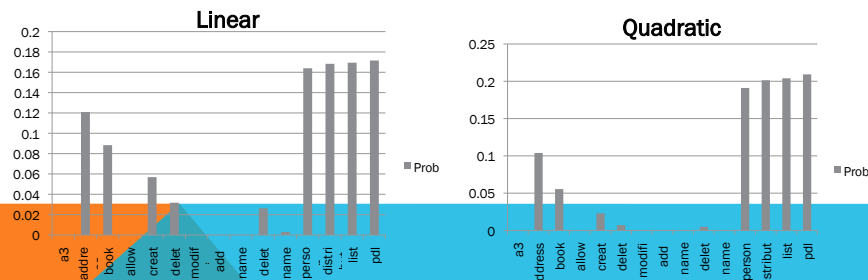
Reinforcement Learning

Linear

$$\Pr(\text{State}_i) = \frac{\text{Value}(S_i)}{\sum_{j \in \text{possible states}} (S_j)}$$

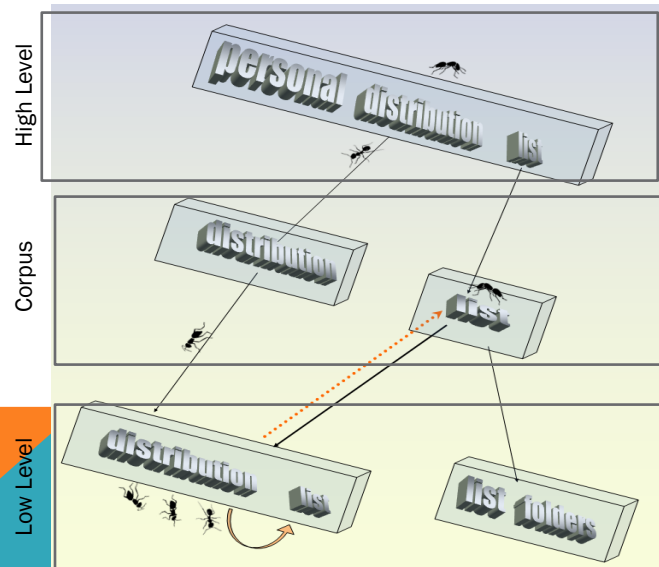
Quadratic

$$\Pr(\text{State}_i) = \frac{\text{Value}(S_i * S_i)}{\sum_{j \in \text{possible states}} (S_j * S_j)}$$



25

Traceability using Agents



Traceability using Agents

Example

– A1.txt - 100 agents

– End up

- UC1.TXT - 50 (1.0),
 - UC2.TXT - 35 (0.7)
-

- UC3.txt - 10 (0.2)

- UC4.txt 5 (0.1)

- Threshold to filter candidate link

- Filter varies from 0.1 to 0.9

27

RL approach

Build search space

- Five types of states
- State transition probabilities
- Maximize rewards

Send agents

Collect counts at low level elements

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29

Related Work

Machine Learning - Menczer and Belew work

Similarities [17]

- Autonomous agents
- Current neighborhood
- Reinforcement learning

Differences

- Web links
- User feedback
- Initial reservoir of energy

30

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31

Validation

Two case studies

- Pine - text-based email system
49 requirements, 51 textual use cases (246)
- CM1SUB - NASA scientific instrument 22 requirements, 53 design elements (45)

32

Validation

RL algorithm applied (and tf-idf)

Output captured, compared to answer set

Recall, precision calculated

33

Validation

Threats to Validity

Conclusion validity

- Statistics

Internal validity

- Answer Set
- Consistent Measurements

34

Validation

Hypotheses

The Null hypothesis, H_0 :

$$H_0: P_{RL} = P_{tf-idf}$$

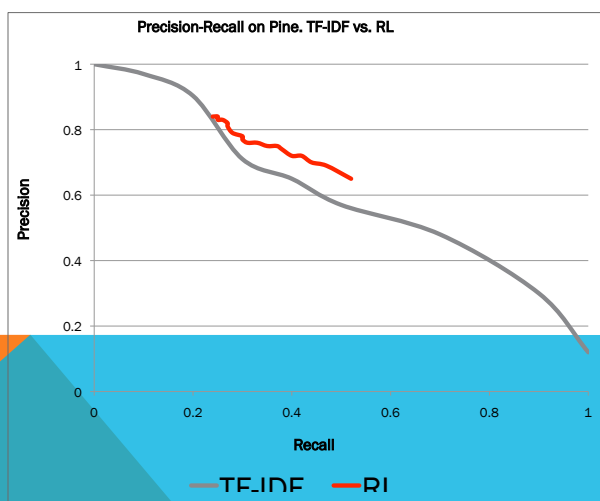
The alternative hypothesis, H_A :

$$H_A: P_{RL} > P_{tf-idf}$$

35

Validation

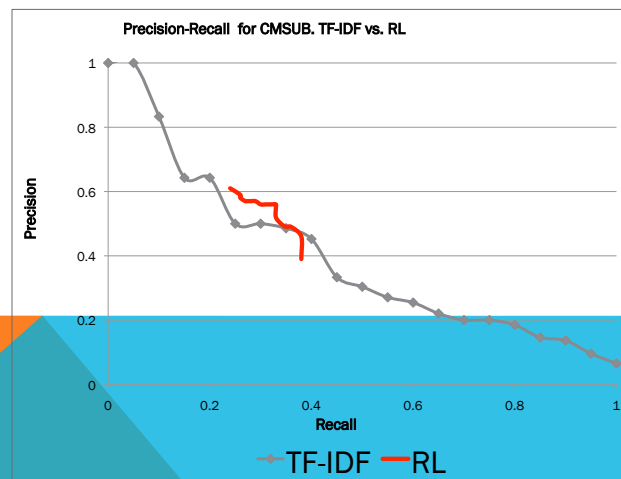
RESULTS: PINE DATASET



36

Validation

RESULTS: CM1SUB DATASET



37

Validation

Statistical Analysis

RL on Pine

Wilcoxon Signed Ranked

Z_{critical} test was ± 1.96 at confidence level $\alpha = 0.05$

- $W_- = -205,$
- $W_+ = 20,$
- $Z = -3.82.$

38

Validation

Statistical Analysis

RL on CM1SUB

Wilcoxon Signed Ranked

Z_{critical} test was ± 1.96 at confidence level $\alpha = 0.05$

- $W_- = -153,$
- $W_+ = 18.5,$
- $Z = -3.07.$

39

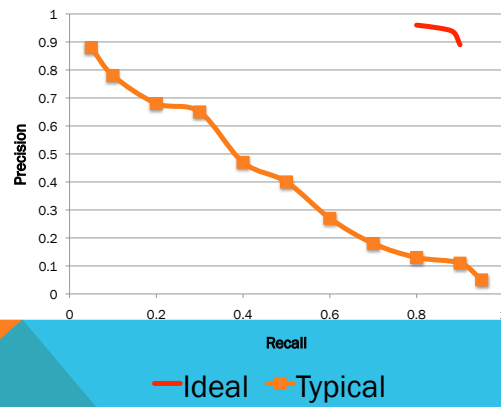
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40

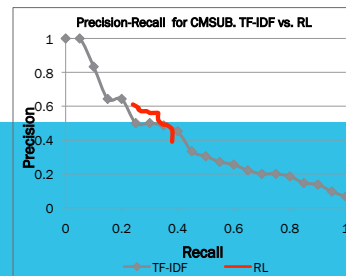
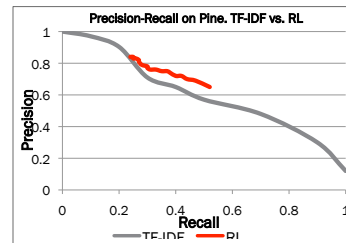
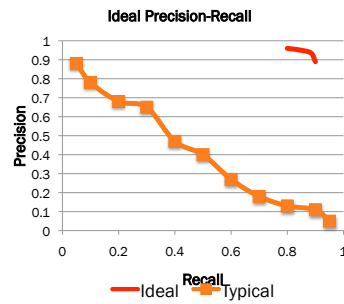
Observations

Ideal Precision-Recall



41

Observations



42

Observations

Common textual segments contribute significantly to promoting possible link between documents

43

Future work

- Feedback mechanism
- Part of speech tagging

44

References

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45

Questions?



A view of 7 year old child on how ants travel

46

Artifacts as Search Space (cont'd)

