Advance in Software Engineering Research

Service Analytics: Concept and Applications

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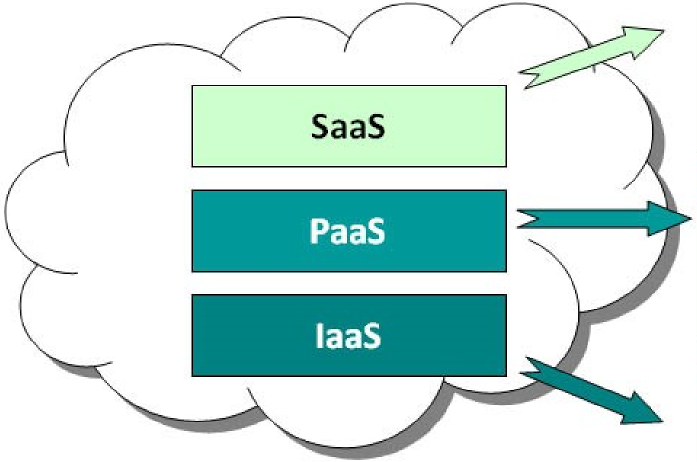
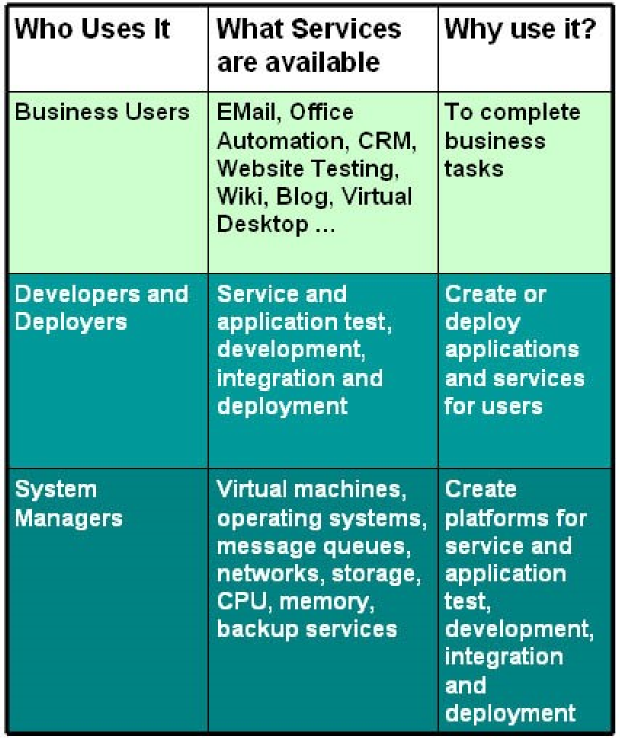
Cloud Era





Who Uses It	What Services are available	Why use it?
Business Users	EMail, Office Automation, CRM, Website Testing, Wiki, Blog, Virtual Desktop ...	To complete business tasks
Developers and Deployers	Service and application test, development, integration and deployment	Create or deploy applications and services for users
System Managers	Virtual machines, operating systems, message queues, networks, storage, CPU, memory, backup services	Create platforms for service and application test, development, integration and deployment

Software is changing...

On-premise
License
Small Scale

bing
MS Beta 0

facebook

Facebook helps you connect and share with the people in your life.

ebay

twitter

msn

amazon

Microsoft Office 365

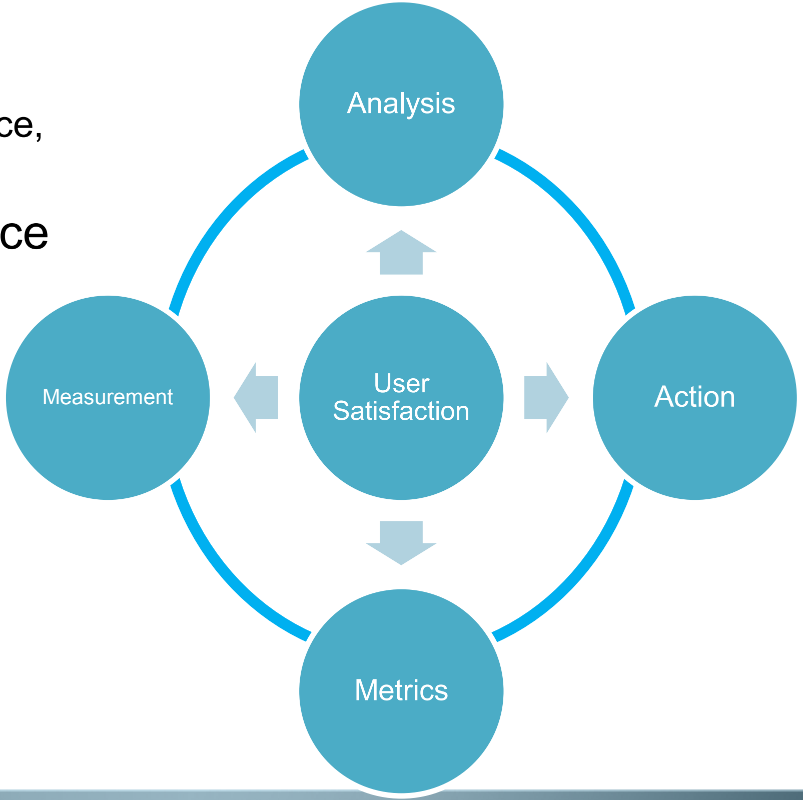
Online Services
Subscription
Large Scale

How software is built & operated is changing

Code centric	User centric
In-lab testing	Debugging in the large
Experience & gut-feeling	Data-driven decision making
Centralized development	Distributed development
Long product cycle	Continuous release
…	…

User-Centric Service

- Aspects of user satisfaction
  - Usability, reliability, availability, performance, security, privacy, power consumption, …
- User satisfaction as a key driving force for success
  - Prioritization guideline
  - Optimization target
  - Design goal
- Data-driven user satisfaction
  - Metrics
  - Measurement
  - Analysis
  - Action

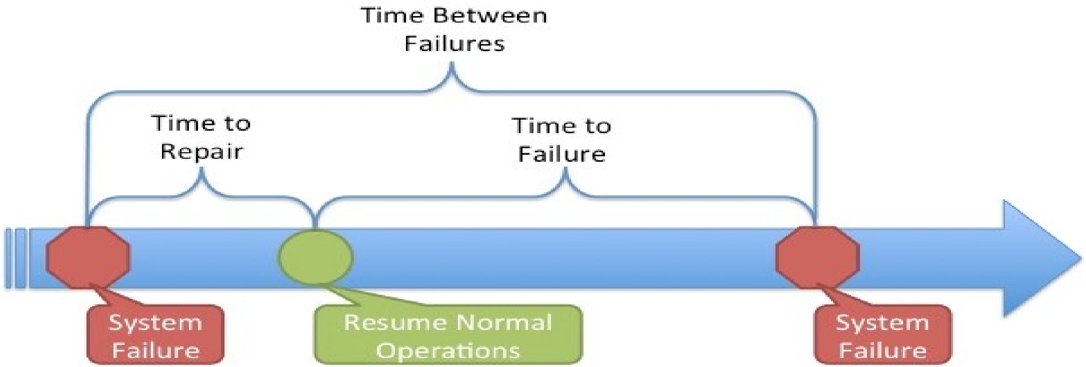


Reality – 故障不可避免!?

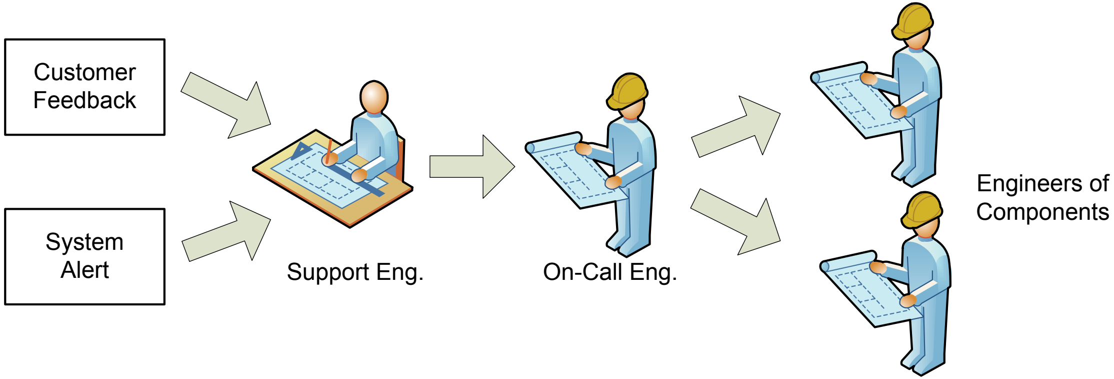
- Google
  - Gmail 在2012/4， 2012/6/07， 2013/8/17, 2014/1/24 等多次发生故障，影响超3300万人
  - 最近一次Google搜索故障，2014/8/27，搜啥都是车祸图片
- Microsoft
  - 2014/11/18 Windows Azure故障
- 微信
  - 2011/12/14, 2013/4/10, 2013/7/22, 2013/8/20, 2014/10/20

Service Quality Management

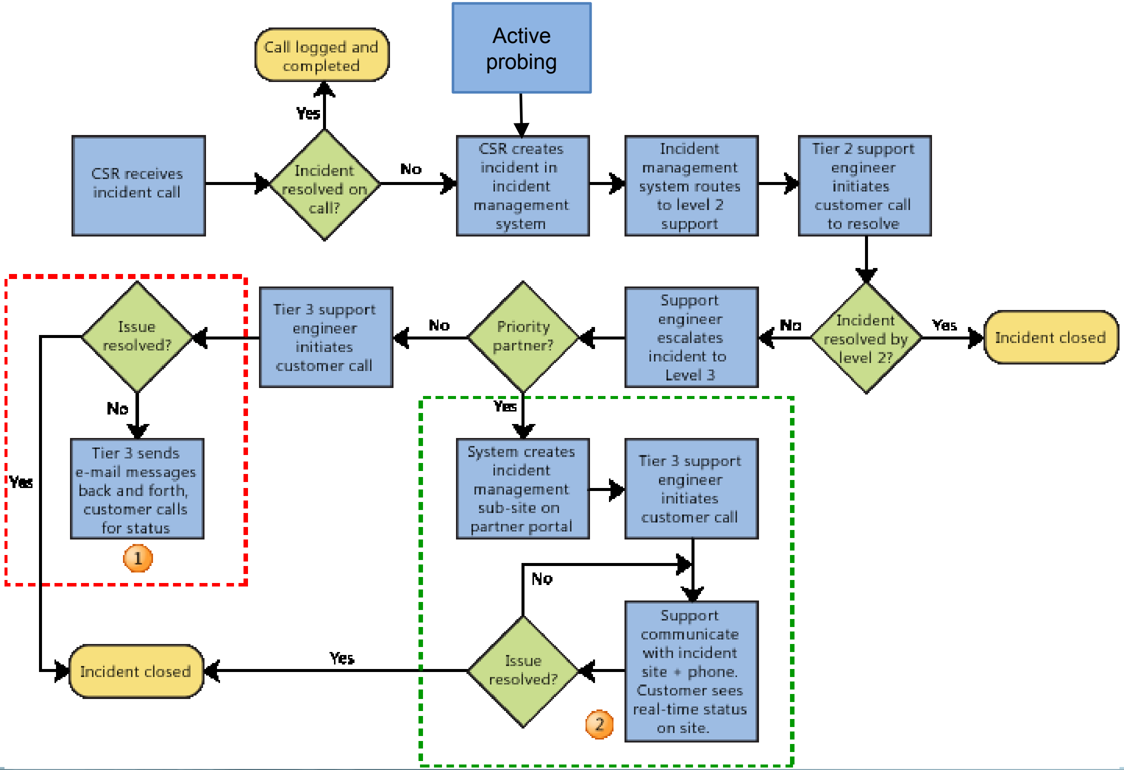
Service-Quality Metrics		Managing Process
MTTR (mean time to repair)	⇐	Incident management (ICM)
MTTF (mean time to failure)	⇐	Problem management



Incident Management



Incident Management: An Example

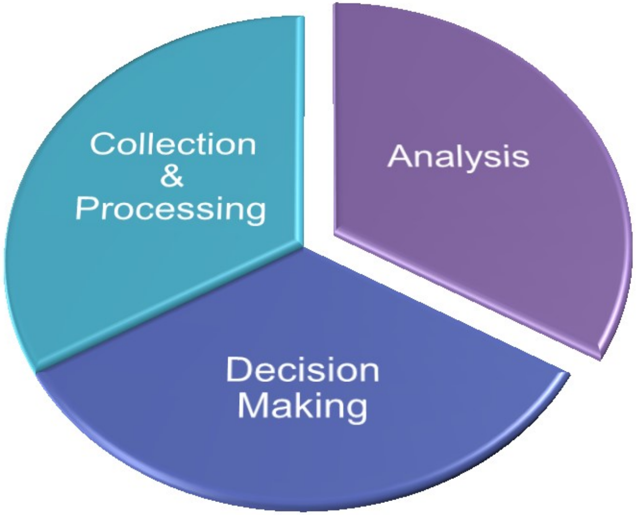

Call logged and completed
Active probing
Yes
CSR receives incident call
Incident resolved on call?
No
CSR creates incident in incident management system
Incident management system routes to level 2 support
Tier 2 support engineer initiates customer call to resolve
Issue resolved?
Tier 3 support engineer initiates customer call
No
Priority partner?
Support engineer escalates incident to Level 3
No
Incident resolved by level 2?
Yes
Incident closed
No
Yes
Tier 3 sends e-mail messages back and forth, customer calls for status
1
Yes
System creates incident management sub-site on partner portal
Tier 3 support engineer initiates customer call
No
Support communicate with incident site + phone. Customer sees real-time status on site.
Incident closed
Yes
Issue resolved?
2

缺点：

1. 没有自动化
2. 故障只等着用户汇报

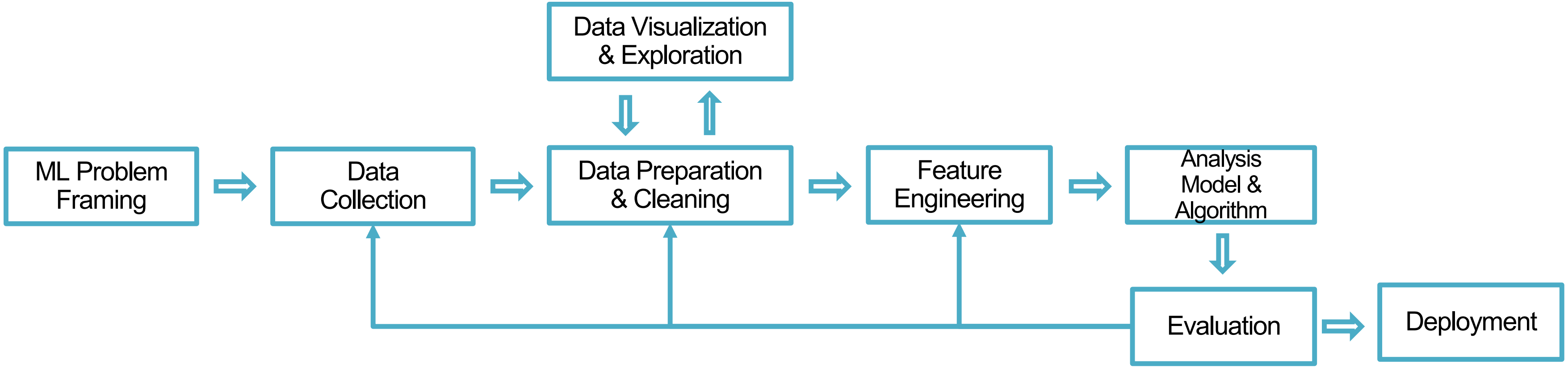
What is the Key?

Service engineering processes are moving to data-driven

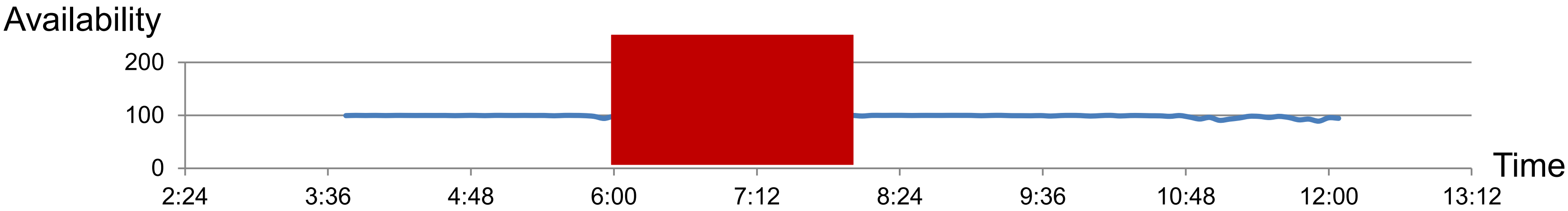


Formulation: Service Analytics

Service analytics is to enable service ***practitioners*** to perform *data exploration and analysis* in order to quickly conduct service management tasks.


Data Visualization & Exploration
ML Problem Framing
Data Collection
Data Preparation & Cleaning
Feature Engineering
Analysis Model & Algorithm
Evaluation
Deployment

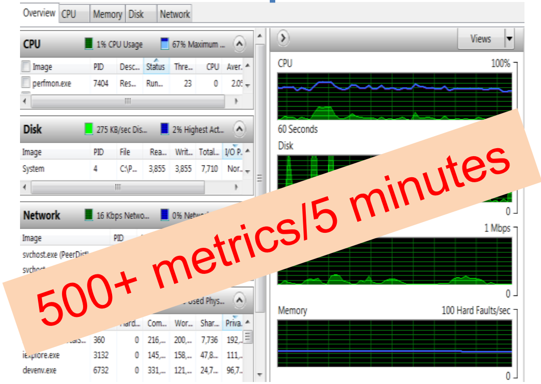
Logs Generated by An Online Service



System Resource Measurements

System Events

Transaction Processing event logs



CPU 1% CPU Usage 67% Maximum ...

Image	PID	Desc...	Status	Thre...	CPU	Aver...
perfmon.exe	7404	Res...	Run...	23	0	2.0

Disk 275 KB/sec Dis... 2% Highest Act...

Image	PID	File	Rea...	Writ...	Total...	I/O P...
System	4	C:\P...	3,855	3,855	7,710	Nor...

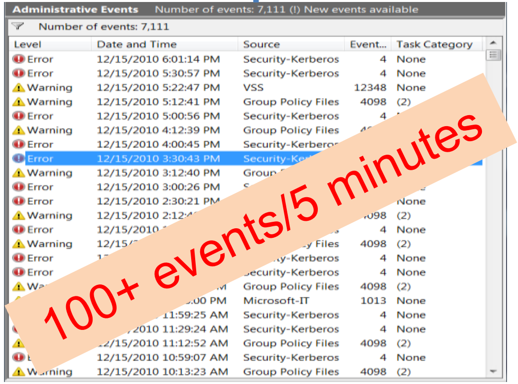
Network 16 Kbps Netwo... 0% Netw...

Image	PID
svchost.exe (PeerDist	
svchost	

...Used Phys...

Image	PID	Hard...	Com...	Wor...	Shar...	Priva...
...tas...	360	0	216,...	200,...	7,736	192,...
iexplore.exe	3132	0	145,...	158,...	47,8...	111,...
devenv.exe	6732	0	331,...	121,...	24,7...	96,7...

500+ metrics/5 minutes

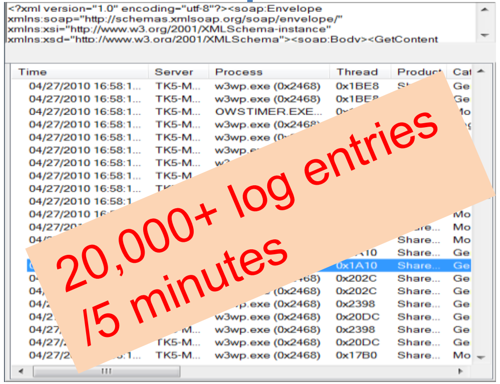


Administrative Events Number of events: 7,111 (!) New events available

Number of events: 7,111

Level	Date and Time	Source	Event...	Task Category
Error	12/15/2010 6:01:14 PM	Security-Kerberos	4	None
Error	12/15/2010 5:30:57 PM	Security-Kerberos	4	None
Warning	12/15/2010 5:22:47 PM	VSS	12348	None
Warning	12/15/2010 5:12:41 PM	Group Policy Files	4098	(2)
Error	12/15/2010 5:00:56 PM	Security-Kerberos	4	
Warning	12/15/2010 4:12:39 PM	Group Policy Files	4	
Error	12/15/2010 4:00:45 PM	Security-Kerberos		
Error	12/15/2010 3:30:43 PM	Security-Ke		
Warning	12/15/2010 3:12:40 PM	Group		
Error	12/15/2010 3:00:26 PM	S		
Error	12/15/2010 2:30:21 PM			None
Warning	12/15/2010 2:12:		098	(2)
Error	12/15/2010		4	None
Warning	12/15/	y Files	4098	(2)
Error		ty-Kerberos	4	None
Error		ecurity-Kerberos	4	None
Wa	M	Group Policy Files	4098	(2)
	:00 PM	Microsoft-IT	1013	None
	11:59:25 AM	Security-Kerberos	4	None
	2010 11:29:24 AM	Security-Kerberos	4	None
	2/15/2010 11:12:52 AM	Group Policy Files	4098	(2)
E	12/15/2010 10:59:07 AM	Security-Kerberos	4	None
W rning	12/15/2010 10:13:23 AM	Group Policy Files	4098	(2)

100+ events/5 minutes



```
<?xml version="1.0" encoding="utf-8"?><soap:Envelope
xmlns:soap="http://schemas.xmlsoap.org/soap/envelope/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema"><soap:Body><GetContent
```

Time	Server	Process	Thread	Product	Cat
04/27/2010 16:58:1...	TK5-M...	w3wp.exe (0x2468)	0x1BE8	Sh	Ge
04/27/2010 16:58:1...	TK5-M...	w3wp.exe (0x2468)	0x1BE8		Ge
04/27/2010 16:58:1...	TK5-M...	OWSTIMER.EXE...	0x		Mo
04/27/2010 16:58:1...	TK5-M...	w3wp.exe (0x2468			
04/27/2010 16:58:1...	TK5-M...	w3wp.exe (0			
04/27/2010 16:58:1...	TK5-M...	w3wp.e			
04/27/2010 16:58:1...	TK5-M...	w3			
04/27/2010 16:58:1...	TK5-M				
04/27/2010 16:58:1...	TK				
04/27/2010 16:58:1					
04/27/2010 16					Mo
04/27/20				re...	Mo
04/				Share...	Mo
			A10	Share...	Ge
0			0x1A10	Share...	Ge
04		68)	0x202C	Share...	Ge
04/		(0x2468)	0x202C	Share...	Ge
04/		p.exe (0x2468)	0x2398	Share...	Ge
04/2		w3wp.exe (0x2468)	0x20DC	Share...	Ge
04/27/	M...	w3wp.exe (0x2468)	0x2398	Share...	Ge
04/27/	TK5-M...	w3wp.exe (0x2468)	0x20DC	Share...	Ge
04/27/2 :1...	TK5-M...	w3wp.exe (0x2468)	0x17B0	Share...	Mo

20,000+ log entries /5 minutes

Important Scenarios

Problem Detection

Detect potential issues based on system logs, events, counters, usage data, and customer support records

Problem Localization & Diagnosis

Identify the problem site for a service live site issue, or provide information to help pinpoint the potential causes

Problem Categorization & Prioritization

Categorize issues and failures to help understand the trend and prioritize management tasks

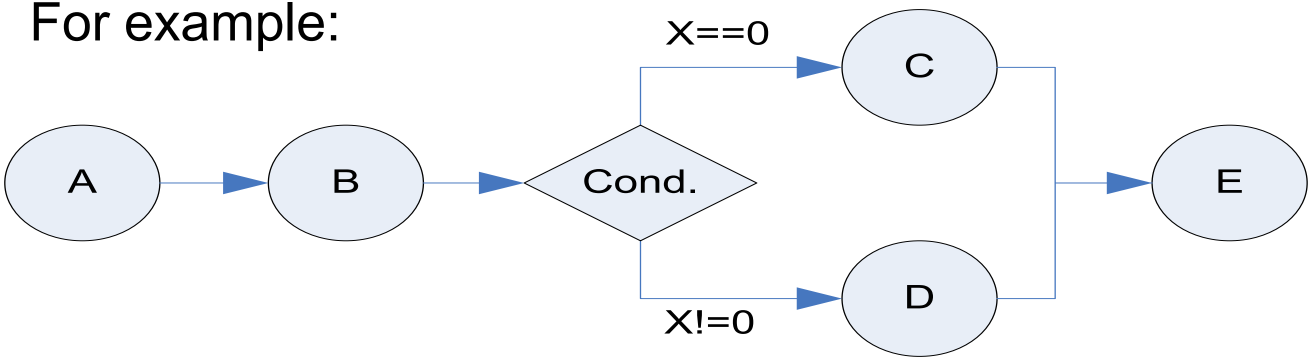
Example 1. mining invariants for service problem detection

Background

- Logs are the major source for telemetry and diagnosis
- Manually inspecting logs is not feasible
  - Large scale of system
  - High complexity of system
- Traditional rule/keyword based log analysis tools:
  - Heavily depend on the knowledge of operators
  - Difficult to keep rules updated when components are frequently revised or upgraded

Linear Program Invariant

- A predicate always holds the same value under different normal executions.
  - For example:

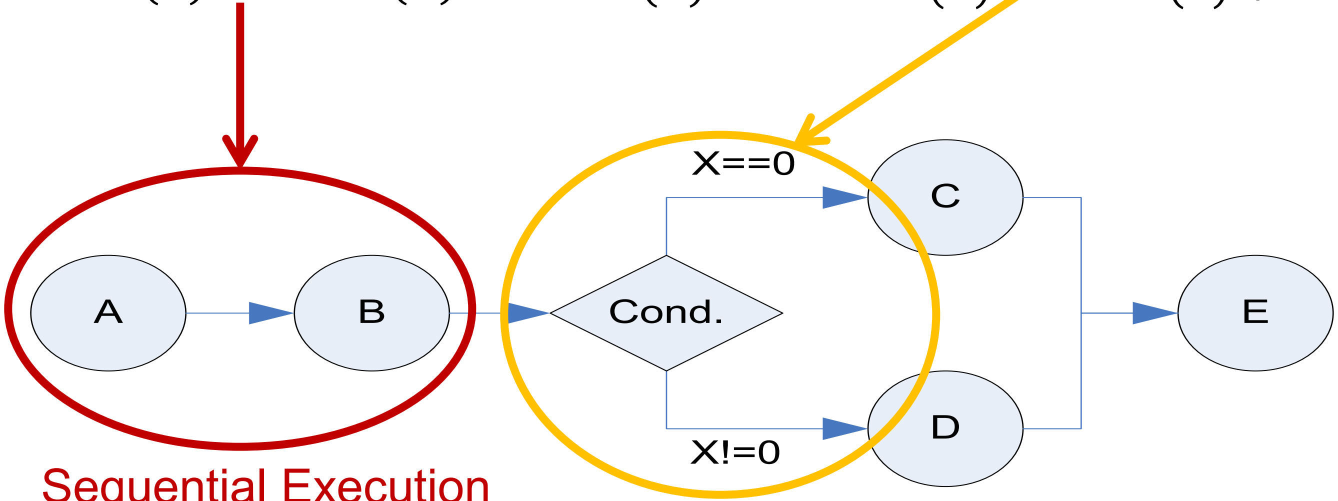


$$count(A) = count(B) = count(E)$$

$$count(B) = count(C) + count(D)$$

Invariant and Execution Path

$count(A) = count(B) = count(E)$ $count(B) = count(C) + count(D)$



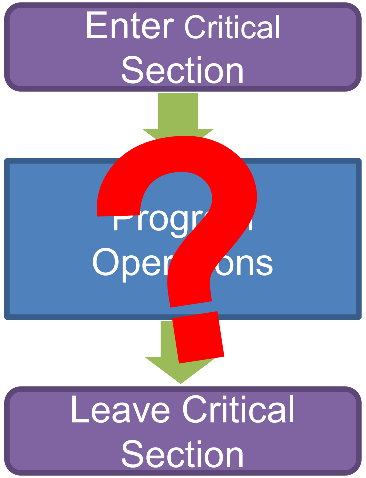
Sequential Execution

Execution Branch

Linear invariants reflect the properties of execution path.

Invariant Violation and Anomaly(1)

- A violation of invariant often indicates a system problem.



$$count(Enter) \neq count(Leave)$$

$$\Downarrow$$

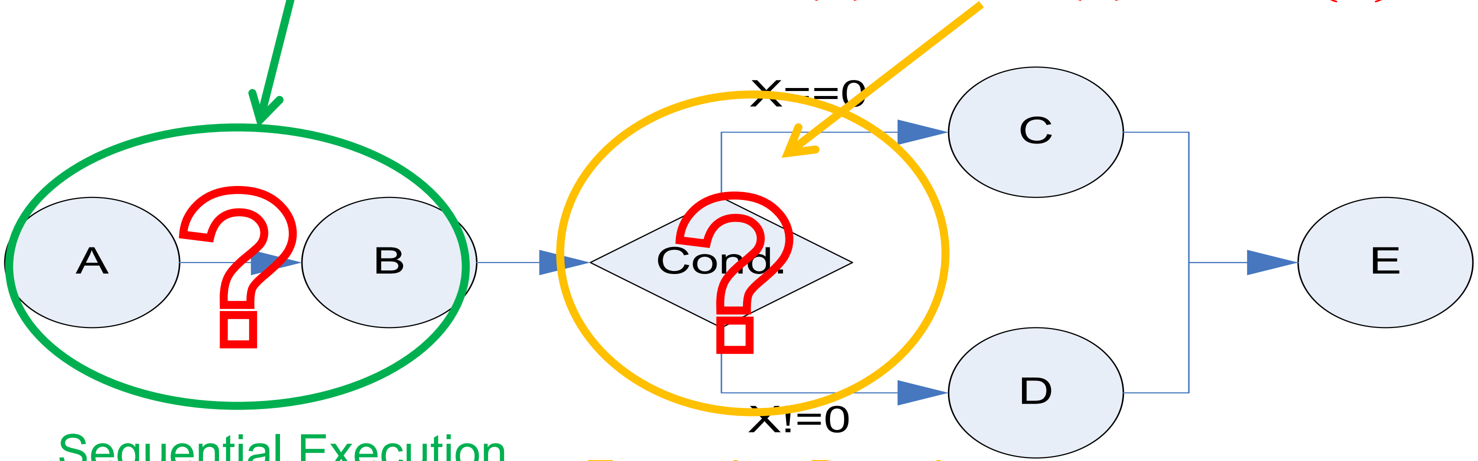
Problem on Critical Section Operations

Invariant Violation and Anomaly(2)

- Violated invariants often give diagnosis cues.

$count(A) > count(B)$

$count(B) > count(C) + count(D)$



Sequential Execution

Execution Branch

Formulation of Invariant

- A linear invariant can be presented as a linear equation:

$$a_0 + a_1 x_1 + a_2 x_2 + \cdots + a_m x_m = 0$$

where x_i is the message count of message i.

- Given a set of logs, we have

$$\boldsymbol{X}\theta = \begin{bmatrix} 1 & x_{11} & x_{12} & \dots & x_{1m} \\ 1 & x_{21} & x_{22} & \ddots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \theta = 0$$

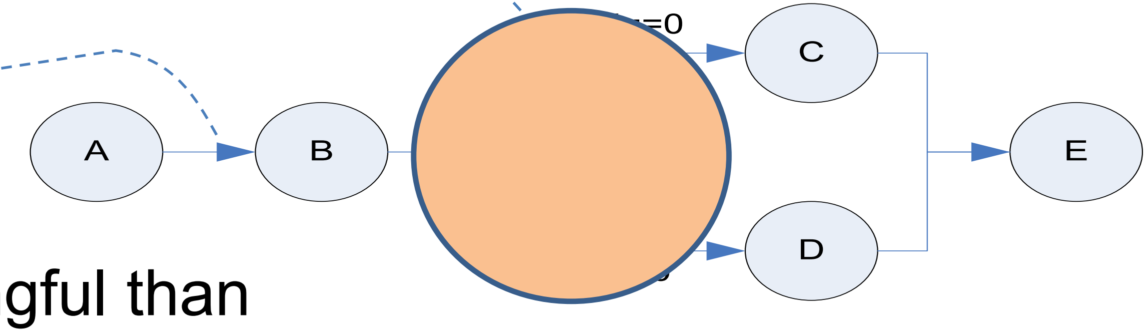
where

$$\theta = [\mathrm{a}_0, \mathrm{a}_1, \mathrm{a}_2, \cdots, \mathrm{a}_\mathrm{m}]^\mathrm{T}$$

What Is A Meaningful Invariant?
-- Sparse Non-zero Coefficients

$$c(B) = c(C) + c(D)$$

$$c(A) = c(B)$$



are more meaningful than

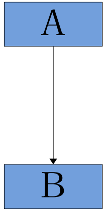
$$c(A) + 3c(B) - 2c(E) - 2c(C) - 2c(D) = 0$$

Any vector in the Null Space of ***X*** is an invariant;

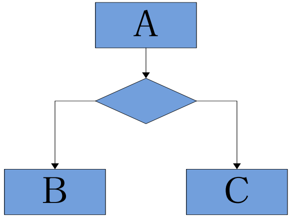
Only sparse invariants are interested.

What Is A Meaningful Invariant?
-- Integer Coefficients

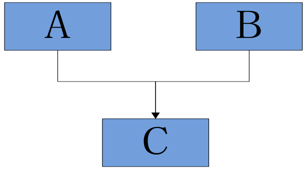
Elementary work flow structures can be interpreted by integer invariants.



Sequential



Branch



Join

… …

Integer invariants are easy to be understood by human operators.

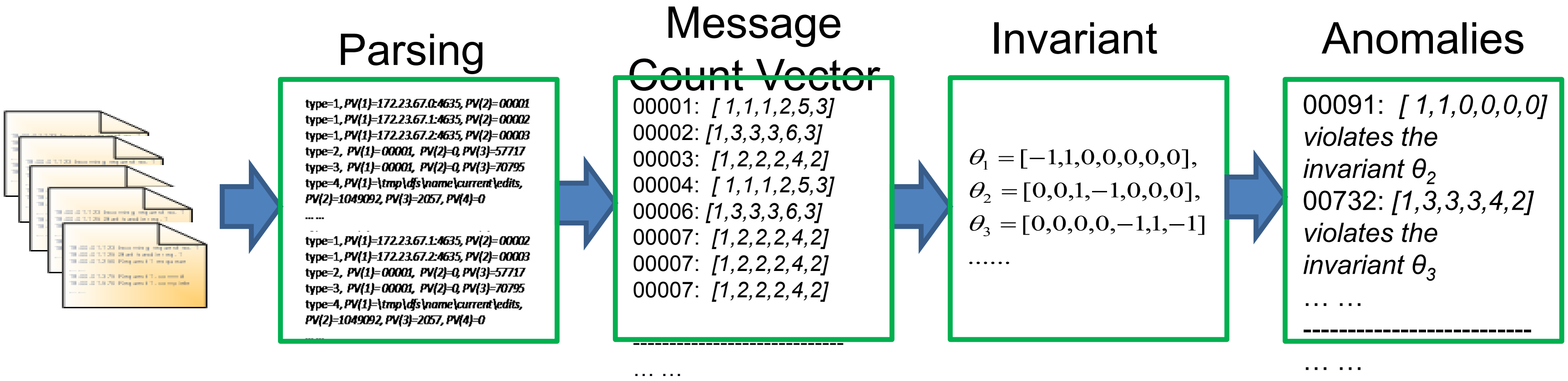
Problem Statement

- Due to noise pollution, mining invariants is to find integer sparse solutions of regression.

$$\boldsymbol{X}\theta = \begin{bmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1m} \\ 1 & x_{21} & x_{22} & \ddots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \theta = 0 \quad \Rightarrow \quad \boldsymbol{arg\,min} \|\boldsymbol{X}\theta\|_{\mathbf{0}}$$

  - Challenges:
    - A typical integer sparse regulation problem (NP-Hard)
    - Traditional method is to relax 0-norm to 1-norm. However, it cannot guarantee to find all invariants.

Learning Invariant Overview



```
type=1, PV(1)=172.23.67.0:4635, PV(2)= 00001
type=1, PV(1)=172.23.67.1:4635, PV(2)= 00002
type=1, PV(1)=172.23.67.2:4635, PV(2)= 00003
type=2,  PV(1)= 00001,  PV(2)=0, PV(3)=57717
type=3,  PV(1)= 00001,  PV(2)=0, PV(3)=70795
type=4, PV(1)=\tmp\dfs\name\current\edits,
PV(2)=1049092, PV(3)=2057, PV(4)=0
--- ---
type=1, PV(1)=172.23.67.1:4635, PV(2)= 00002
type=1, PV(1)=172.23.67.2:4635, PV(2)= 00003
type=2,  PV(1)= 00001,  PV(2)=0, PV(3)=57717
type=3,  PV(1)= 00001,  PV(2)=0, PV(3)=70795
type=4, PV(1)=\tmp\dfs\name\current\edits,
PV(2)=1049092, PV(3)=2057, PV(4)=0
--- ---
```

```
00001:  [ 1,1,1,2,5,3]
00002: [1,3,3,3,6,3]
00003:  [1,2,2,2,4,2]
00004:  [ 1,1,1,2,5,3]
00006: [1,3,3,3,6,3]
00007:  [1,2,2,2,4,2]
00007:  [1,2,2,2,4,2]
00007:  [1,2,2,2,4,2]
------------------------------
… …
```

$$\theta_1 = [-1,1,0,0,0,0,0],$$
$$\theta_2 = [0,0,1,-1,0,0,0],$$
$$\theta_3 = [0,0,0,0,-1,1,-1]$$
……

00091: *[1,1,0,0,0,0] violates the invariant* θ_2

00732: *[1,3,3,3,4,2] violates the invariant* θ_3

… …

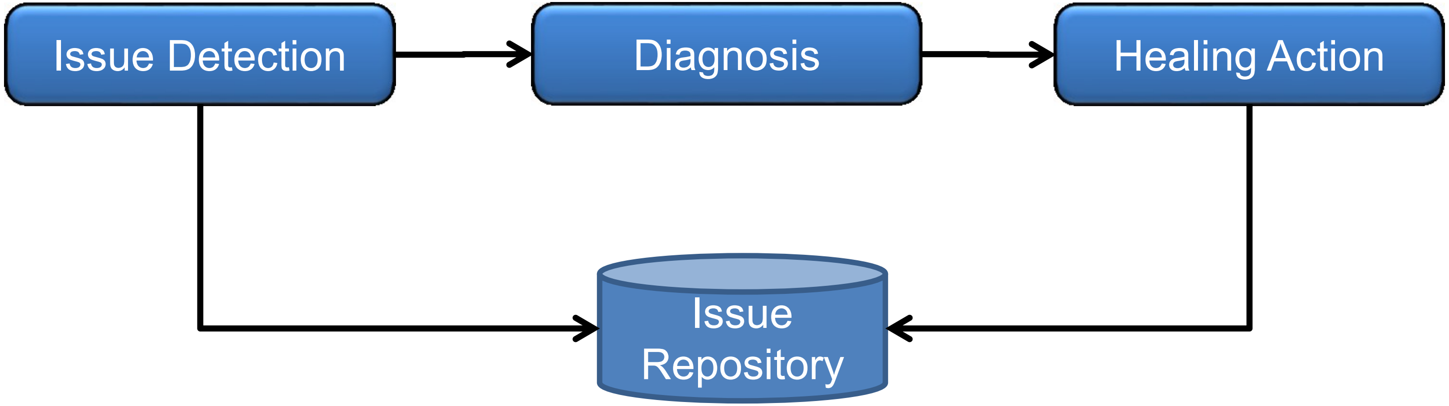
… …

Four Steps:

Auto log parsing, Message Grouping and Counting, Search Invariants, and Anomaly Detection

Example 2. Healing Online Service Systems via Mining Historical Issue Repositories

Motivation

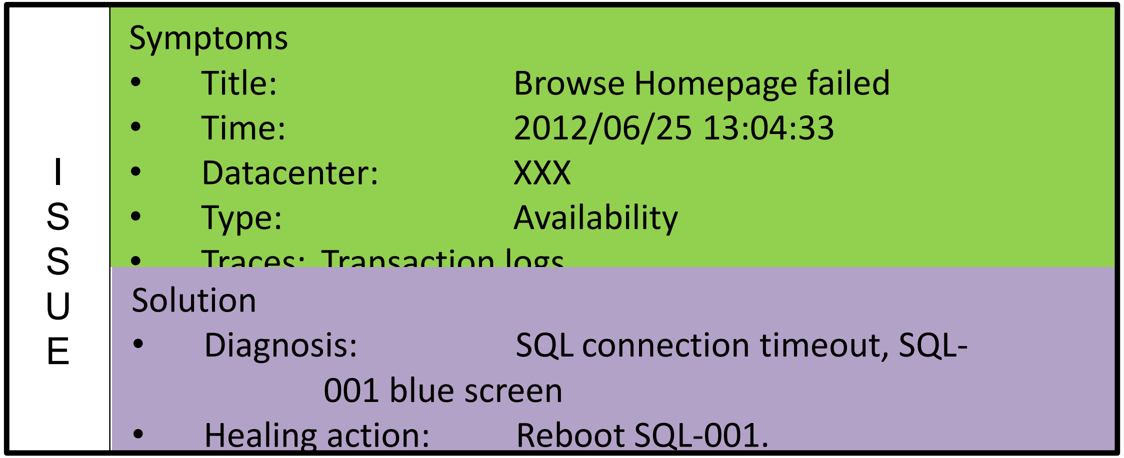


Incident Management Process

When a new issue occurred, how to leverage past diagnosis efforts, to identify proper healing action for the new issue?

A Simple Example of An Issue

- Symptoms
  - Describing the particular sign and phenomena of the issue
- Solution
  - Recording diagnostic steps and resolution



I S S U E

Symptoms

- Title: Browse Homepage failed
- Time: 2012/06/25 13:04:33
- Datacenter: XXX
- Type: Availability
- Traces: Transaction logs

Solution

- Diagnosis: SQL connection timeout, SQL-001 blue screen
- Healing action: Reboot SQL-001.

Simplified example of an issue

Characteristics of Logs

- Highly redundant events

  E.g., 6 events x1 ~ x6 indicate the authentication failure

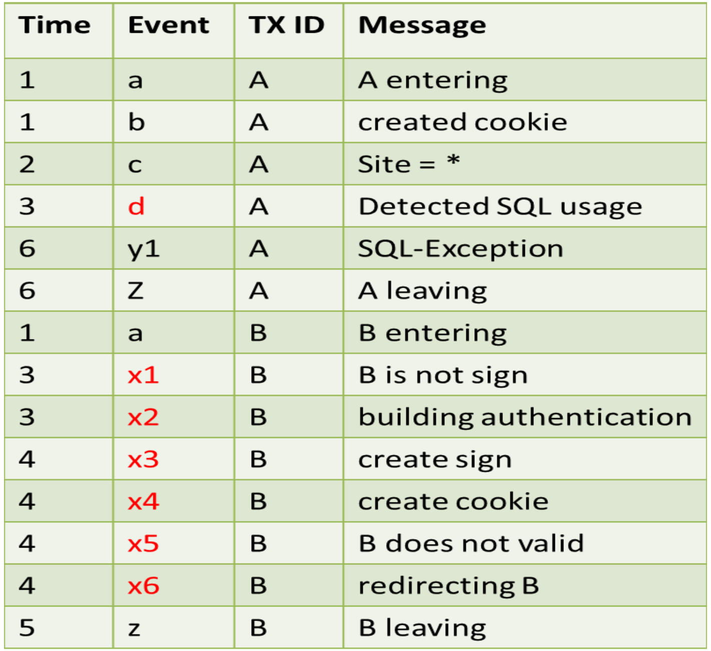
  - Bias issue representation

- Many irrelevant events to failure

  E.g., event d indicates “SQL usage detection”

  - BUT Relevant to issues, e.g., appearing in only SQL-related issues
  - Downgrading discrimination of issue representation

    e.g., one type of SQL issue needs to reboot SQL; another type needs to patch SQL

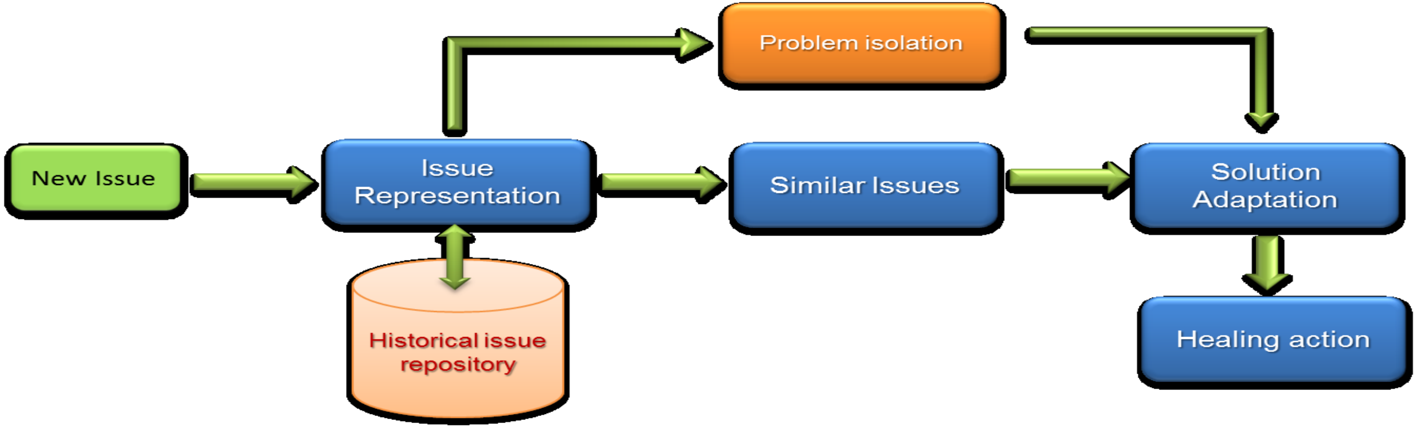


Time	Event	TX ID	Message
1	a	A	A entering
1	b	A	created cookie
2	c	A	Site = *
3	d	A	Detected SQL usage
6	y1	A	SQL-Exception
6	Z	A	A leaving
1	a	B	B entering
3	x1	B	B is not sign
3	x2	B	building authentication
4	x3	B	create sign
4	x4	B	create cookie
4	x5	B	B does not valid
4	x6	B	redirecting B
5	z	B	B leaving

Illustration of transaction logs

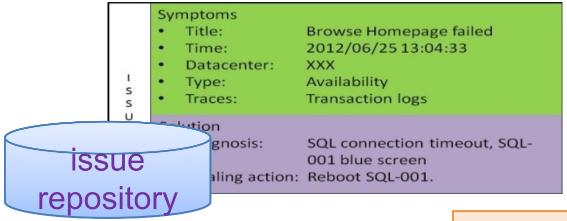
Our Approach

- Issue-signature extraction
  - Address the challenges posed by logs
- Similarity-metric definition
  - Cosine similarity based on Generalized Vector Space Model (GVSM)
- Healing-action adaptation
  - Structured healing action + fault localization



Signature Extraction

An Issue

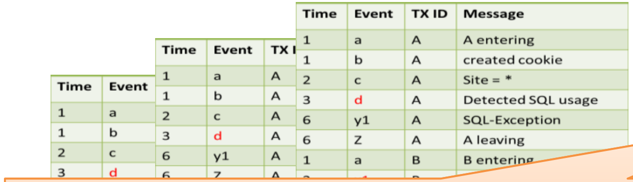


Symptoms
- Title: Browse Homepage failed
- Time: 2012/06/25 13:04:33
- Datacenter: XXX
- Type: Availability
- Traces: Transaction logs

Solution
gnosis: SQL connection timeout, SQL-001 blue screen
aling action: Reboot SQL-001.

Parsing log messages

Log Sequences



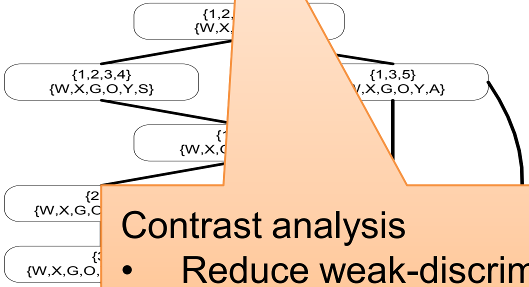
Time	Event	TX ID	Message
1	a	A	A entering
1	b	A	created cookie
2	c	A	Site = *
3	d	A	Detected SQL usage
6	y1	A	SQL-Exception
6	Z	A	A leaving
1	a	B	B entering

Formal concept analysis
- Reduce redundancy
- Extract trunk/branch relationship of execution paths

Issue Signature

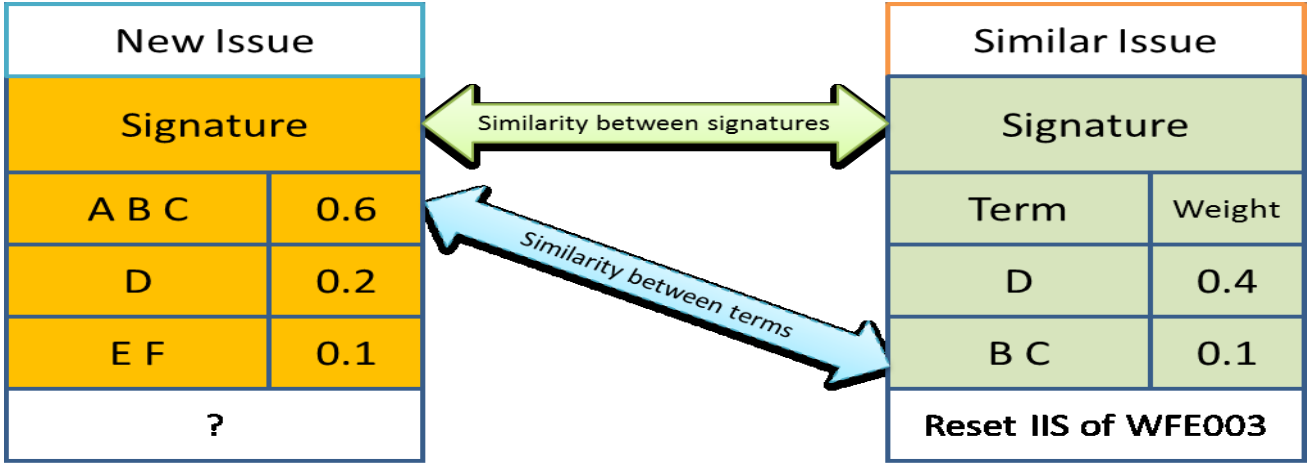
Index	Term (Event Set)	DMI
1	X G T	0.34
2	N S O Y	0.21
3	B C	0.07

Conce t Lattice



Contrast analysis
- Reduce weak-discrimination
- Measure correlation with Delta Mutual Information (DMI)

Issue Comparison

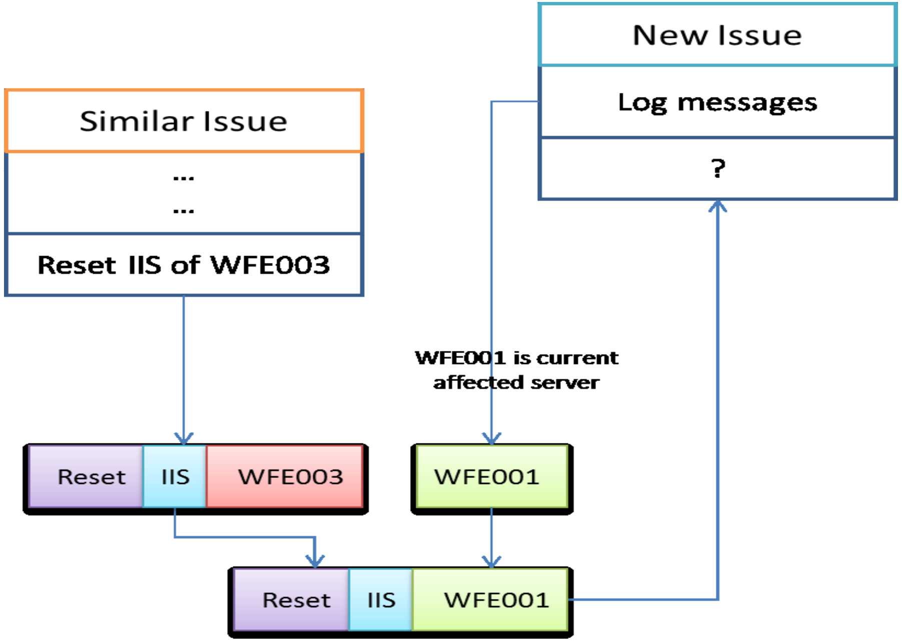


Similarity definition: (Generalized Vector Space Model)

- Similarity between terms
- Similarity between signatures
  - Combine term similarity
  - Encode importance of term using DMI as weights

Healing-Action Adaptation

- Triple structure
  - $< verb, target, locaton >$
- *Verb & Target*
  - E.g., *"recycle + AppPool", "Reset + IIS*
  - Extracted from retrieved similar issues by analyzing their solution descriptions
- Location
  - Specific machine/server name, e.g., SQL23524-001
  - Obtained by applying fault-localization techniques



Evaluation

---Internal production service: ServiceX

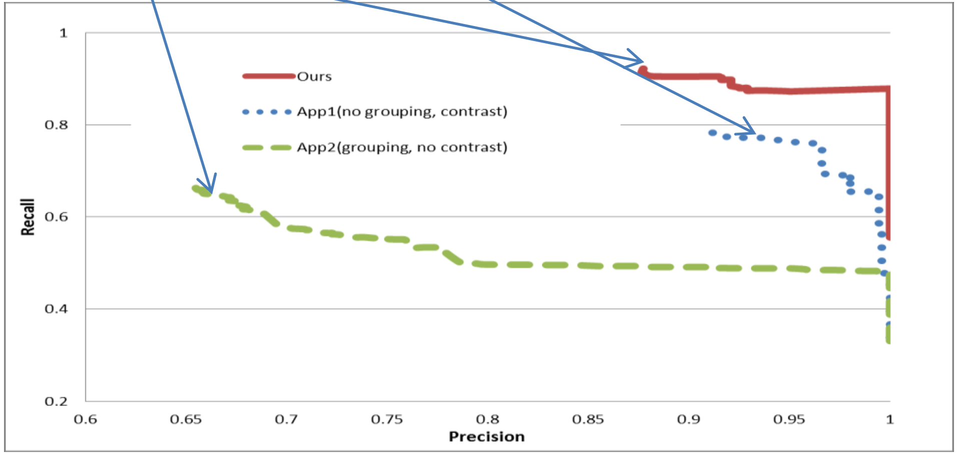
- 332 issues collected in time period: 11/01/2011~02/18/2012
- 146 issues with documented healing actions and recorded logs

69 issues on service upgrade

77 issues on service interruption or degradation

- – used in evaluation

- Effect of our techniques on overall effectiveness
  - – Approach1: Ignore highly-correlated phenomenon (Mutual information + VSM)
  - – Approach2: Ignore weakly-discriminative phenomenon (FCA + TF-IDF + VSM)
  - – Our approach: FCA + contrast analysis



Overall ROC curves

Summary

- Mission of Service Analytics
  - Utilize data-driven approach to help create highly performing, user friendly, and efficiently built & operated online services
- Service Analytics is naturally tied with state of engineering practice of service
- Empowering future software practitioners with data analytics mindset & skills

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- We are recruiting!
  - Software analytics researchers (Full-time employee, visiting researchers)
  - Software analytics interns

Q & A

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