CAT Detect: A Tool for Detecting Inconsistency in Computer Activity Timelines

By

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Presented At

The Digital Forensic Research Conference

DFRWS 2011 USA New Orleans, LA (Aug 1st - 3rd)

CAT Detect: A tool for detecting inconsistency in computer activity timelines

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Motivation

- Construction of timelines of computer activity is important to many investigations.
  - From system logs, file MAC times, file metadata
- Whether through deliberate tampering, software misconfiguration/bug, hardware clock skew/drift or other “natural” cause, these timestamps may be inconsistent or contradictory.

Computer Activity Timelines

- A computer activity timeline is a sequence of *events* ordered by time.
- Events have two sources:
  - System logs (e.g. the Windows Event Logs) – we call these *recorded events*
  - Timestamps from the file system and metadata (e.g. MAC times, Exif creation times) – we call these *inferred events*
- A complete-as-possible timeline of computer activity combines recorded and inferred events, ordered by time.

Inconsistent Timelines

- Out-of-sequence events
  - Events whose timestamp is inaccurate
  - These events appear to have taken place after other events, even though logically they should have taken place beforehand
- Missing events
  - Events which logically must have taken place but…
  - …are absent from our timeline!

Sources of Inconsistency

- Out-of-sequence events and missing events can be caused through “normal” operation or deliberate tampering or obfuscation.
- “Natural” causes include:
  - System logging configuration – by default many events may go unrecorded, making them “missing”
  - Clock skew and drift, and the variations in clock skew over time
  - Laptops moving between timezones etc

Detecting Inconsistency

- Approach

Tool Environment

- System log parsers
- Event inferrer

- RecordedEvents table
- InferredEvents table

- Rules base

Events

- Events are extracted from system logs (e.g. Windows Event Logs) using a log parsing tool.
  - We have been using our own parser, but other tools are now available with a great deal more maturity, e.g. GrokEVT
- Events are inferred from timestamps extracted from the file system and file metadata.
  - These could extracted from other tools.
  - We have been using our own event inferrer, which we hope to make available soon.

Normalised format

- Events are normalised into the following format:

  Time, Subject, Object, Result, Action.

- With the addition of an “Event ID” field, these are stored in two database tables: *RecordedEvents* and *InferredEvents*.

Rules Base

- The rules base includes some template events
  - e.g. template login and logoff events
- The rules base also includes rules which define the relations which should exist between certain events in order for them to be consistent
- CAT Detect checks the events in a given timeline against the rules base.
- At the moment, these rules are statically defined in-code but this should be improved upon soon.

Happened before relation…

- Some types of events must logically *happen before* other events.
- For example, the user must login before the user can create a file.
- This sort of relation is described by Leslie Lamport (1978) as the *happened-before* relation.
  - Expanded by Fidge (1991) and used in a DF context by Gladyshev and Patel (2005) and Willassen (2008).
- This relation is used as the basis of our rules.

Detecting out-of-sequence events

- A user *x* must login to the computer system before creating file *y* on the computer system's drive. Each of these is an event:
  - evtA = (t_a, *x*, system, login, success)
  - evtB = (t_b, *x*, *y*, created, success)
- The rule will specify that evtA must *happen-before* evtB (evtA → evtB).
- If $t_a < t_b$, then evtA and evtB are inconsistent.
- If $t_a > t_b$, then the events break this rule and are inconsistent.

Preconditions and Missing Events

- In some relations, the presence of the second event necessarily implies the presence of the first event.
- Extending our last example, we can say that evtA is a precondition of evtB.
- If evtA does not exist in our database, therefore, it is a *missing event* whose presence has been inferred.

Why do we need both?

- Let us define a third event, whereby a user *x* logs off the computer system:
  - evtC = (t_c, *x*, system, logoff, success)
- It is clear that evtB → evtC, and that evtA is a precondition of evtC.
- It is also clear that evtB (a file creation event) is not necessary for evtC to take place.

CAT Detect

- Usage Experiment

Experiment

- We extracted our data from a Windows XP test PC with several dummy user accounts created on it:
  - baddie
  - crook
  - nefarious
- We normalised the event logs and loaded them into the *RecordedEvents* table.
- We ran our event inferrer over the disk image and loaded its output into the *InferredEvents* table.

Experimental Timelines

- Timeline A – consistent timeline, no tampering
- Timeline B – inconsistent timeline, “crook” logged in but files apparently created by “baddie”
- Timeline C – inconsistent timeline, missing logon event
- Timeline D – inconsistent timeline, timestamp of logoff event altered.

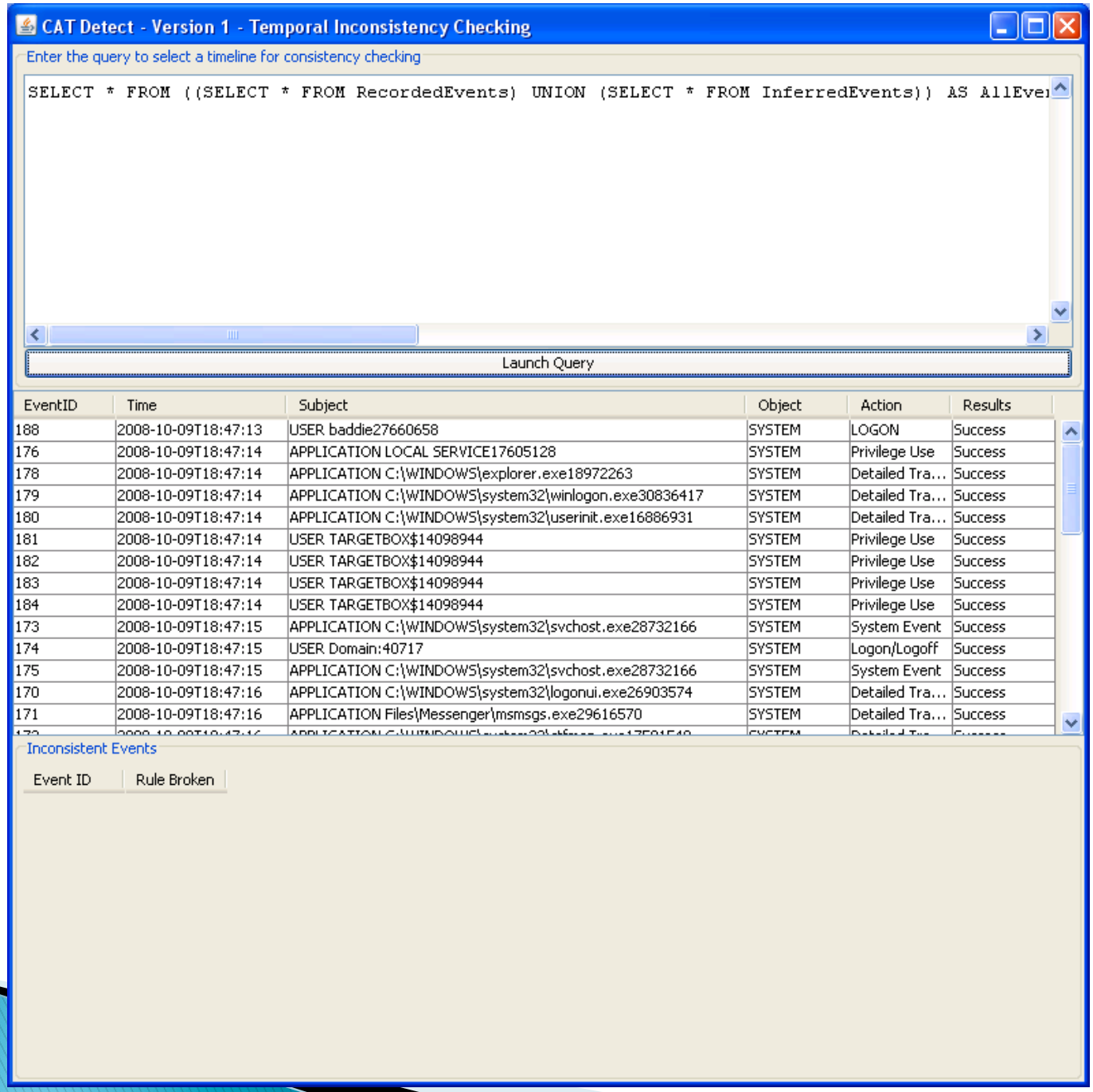
Limitations

- This release of CAT Detect has several limitations
- Most notably, as you will see, the user must provide a query to specify the timeline corresponding to the user login session in which they are interested.

Timeline A

- Query:

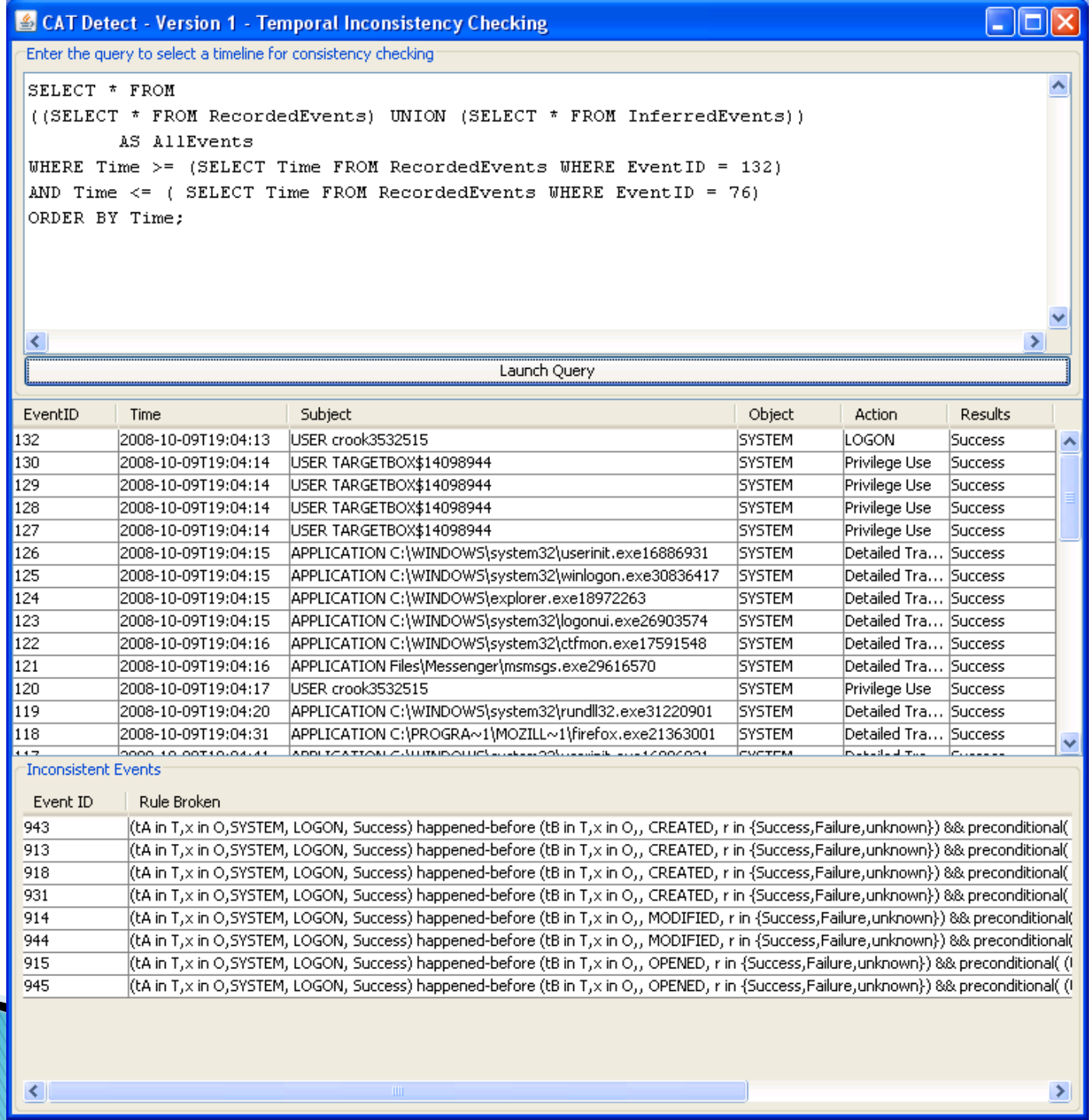
```
SELECT * FROM
((SELECT * FROM RecordedEvents) UNION
  (SELECT * FROM InferredEvents))
  AS AllEvents
WHERE Time >= (SELECT Time FROM
  RecordedEvents WHERE EventID = 188)
AND Time <= ( SELECT Time FROM
  RecordedEvents WHERE EventID = 146)
  ORDER BY Time;
```


CAT Detect - Version 1 - Temporal Inconsistency Checking
Enter the query to select a timeline for consistency checking
SELECT * FROM ((SELECT * FROM RecordedEvents) UNION (SELECT * FROM InferredEvents)) AS AllEve
Launch Query
EventID
Time
Subject
Object
Action
Results
188 2008-10-09T18:47:13 USER baddie27660658 SYSTEM LOGON Success
176 2008-10-09T18:47:14 APPLICATION LOCAL SERVICE17605128 SYSTEM Privilege Use Success
178 2008-10-09T18:47:14 APPLICATION C:\WINDOWS\explorer.exe18972263 SYSTEM Detailed Tra... Success
179 2008-10-09T18:47:14 APPLICATION C:\WINDOWS\system32\winlogon.exe30836417 SYSTEM Detailed Tra... Success
180 2008-10-09T18:47:14 APPLICATION C:\WINDOWS\system32\userinit.exe16886931 SYSTEM Detailed Tra... Success
181 2008-10-09T18:47:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Success
182 2008-10-09T18:47:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Success
183 2008-10-09T18:47:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Success
184 2008-10-09T18:47:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Success
173 2008-10-09T18:47:15 APPLICATION C:\WINDOWS\system32\svchost.exe28732166 SYSTEM System Event Success
174 2008-10-09T18:47:15 USER Domain:40717 SYSTEM Logon/Logoff Success
175 2008-10-09T18:47:15 APPLICATION C:\WINDOWS\system32\svchost.exe28732166 SYSTEM System Event Success
170 2008-10-09T18:47:16 APPLICATION C:\WINDOWS\system32\logonui.exe26903574 SYSTEM Detailed Tra... Success
171 2008-10-09T18:47:16 APPLICATION Files\Messenger\msmsgs.exe29616570 SYSTEM Detailed Tra... Success
Inconsistent Events
Event ID
Rule Broken

Timeline B

- Query:

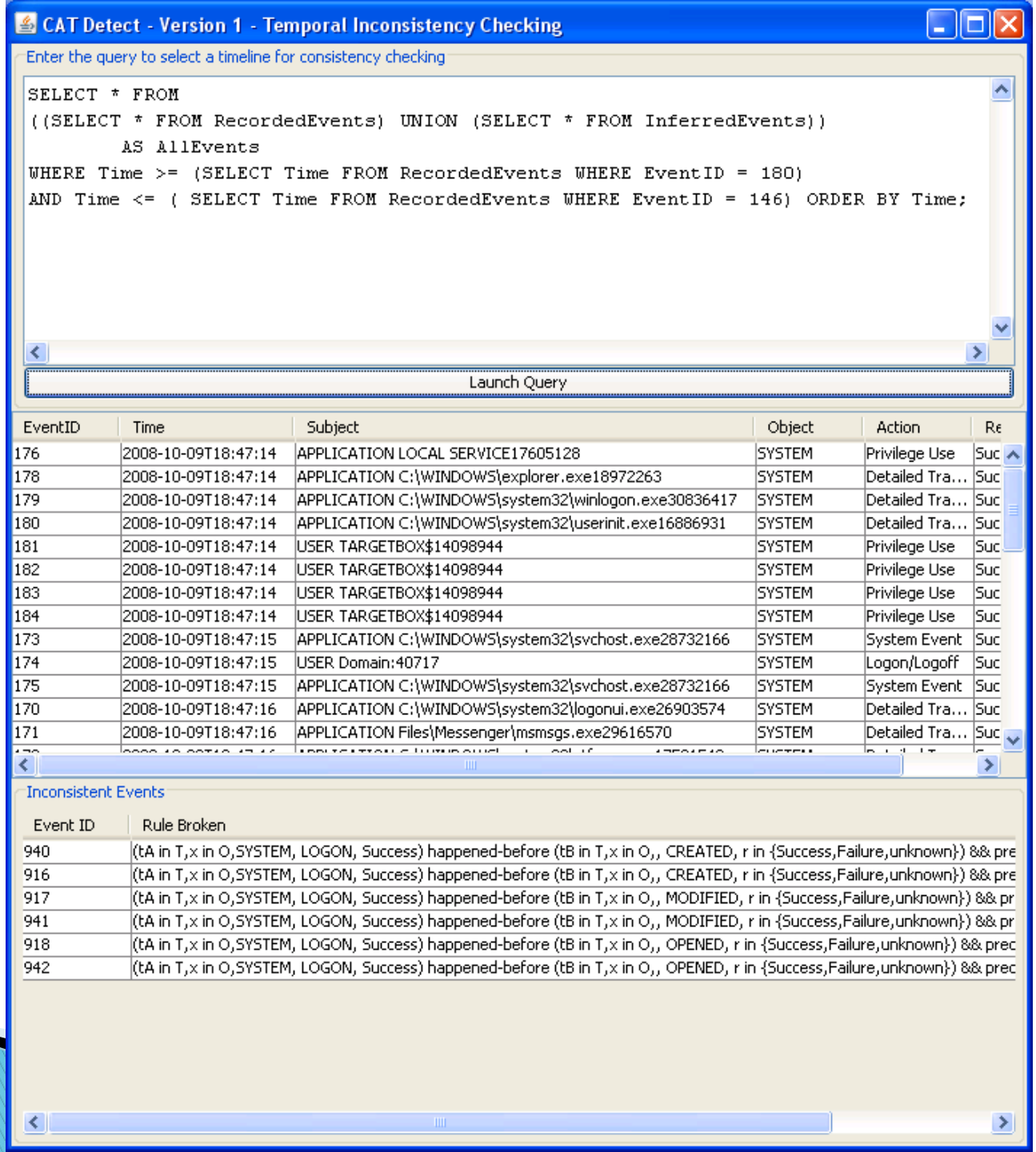
```
SELECT * FROM
((SELECT * FROM RecordedEvents) UNION
  (SELECT * FROM InferredEvents))
  AS AllEvents
WHERE Time >= (SELECT Time FROM
  RecordedEvents WHERE EventID = 132)
AND Time <= ( SELECT Time FROM
  RecordedEvents WHERE EventID = 76)
ORDER BY Time;
```


CAT Detect - Version 1 - Temporal Inconsistency Checking
Enter the query to select a timeline for consistency checking
SELECT * FROM
((SELECT * FROM RecordedEvents) UNION (SELECT * FROM InferredEvents))
AS AllEvents
WHERE Time >= (SELECT Time FROM RecordedEvents WHERE EventID = 132)
AND Time <= (SELECT Time FROM RecordedEvents WHERE EventID = 76)
ORDER BY Time;
Launch Query
EventID Time Subject Object Action Results
132 2008-10-09T19:04:13 USER crook3532515 SYSTEM LOGON Success
130 2008-10-09T19:04:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Success
129 2008-10-09T19:04:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Success
128 2008-10-09T19:04:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Success
127 2008-10-09T19:04:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Success
126 2008-10-09T19:04:15 APPLICATION C:\WINDOWS\system32\userinit.exe16886931 SYSTEM Detailed Tra... Success
125 2008-10-09T19:04:15 APPLICATION C:\WINDOWS\system32\winlogon.exe30836417 SYSTEM Detailed Tra... Success
124 2008-10-09T19:04:15 APPLICATION C:\WINDOWS\explorer.exe18972263 SYSTEM Detailed Tra... Success
123 2008-10-09T19:04:15 APPLICATION C:\WINDOWS\system32\logonui.exe26903574 SYSTEM Detailed Tra... Success
122 2008-10-09T19:04:16 APPLICATION C:\WINDOWS\system32\ctfmon.exe17591548 SYSTEM Detailed Tra... Success
121 2008-10-09T19:04:16 APPLICATION Files\Messenger\msmsgs.exe29616570 SYSTEM Detailed Tra... Success
120 2008-10-09T19:04:17 USER crook3532515 SYSTEM Privilege Use Success
119 2008-10-09T19:04:20 APPLICATION C:\WINDOWS\system32\rundll32.exe31220901 SYSTEM Detailed Tra... Success
118 2008-10-09T19:04:31 APPLICATION C:\PROGRA~1\MOZILL~1\firefox.exe21363001 SYSTEM Detailed Tra... Success
Inconsistent Events
Event ID Rule Broken
943 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, CREATED, r in {Success,Failure,unknown}) && preconditional(
913 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, CREATED, r in {Success,Failure,unknown}) && preconditional(
918 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, CREATED, r in {Success,Failure,unknown}) && preconditional(
931 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, CREATED, r in {Success,Failure,unknown}) && preconditional(
914 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, MODIFIED, r in {Success,Failure,unknown}) && preconditional(
944 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, MODIFIED, r in {Success,Failure,unknown}) && preconditional(
915 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, OPENED, r in {Success,Failure,unknown}) && preconditional((
945 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, OPENED, r in {Success,Failure,unknown}) && preconditional((

Timeline C

- Query:

```
SELECT * FROM
((SELECT * FROM RecordedEvents) UNION
  (SELECT * FROM InferredEvents))
  AS AllEvents
WHERE Time >= (SELECT Time FROM
  RecordedEvents WHERE EventID = 180)
AND Time <= ( SELECT Time FROM
  RecordedEvents WHERE EventID = 146)
  ORDER BY Time;
```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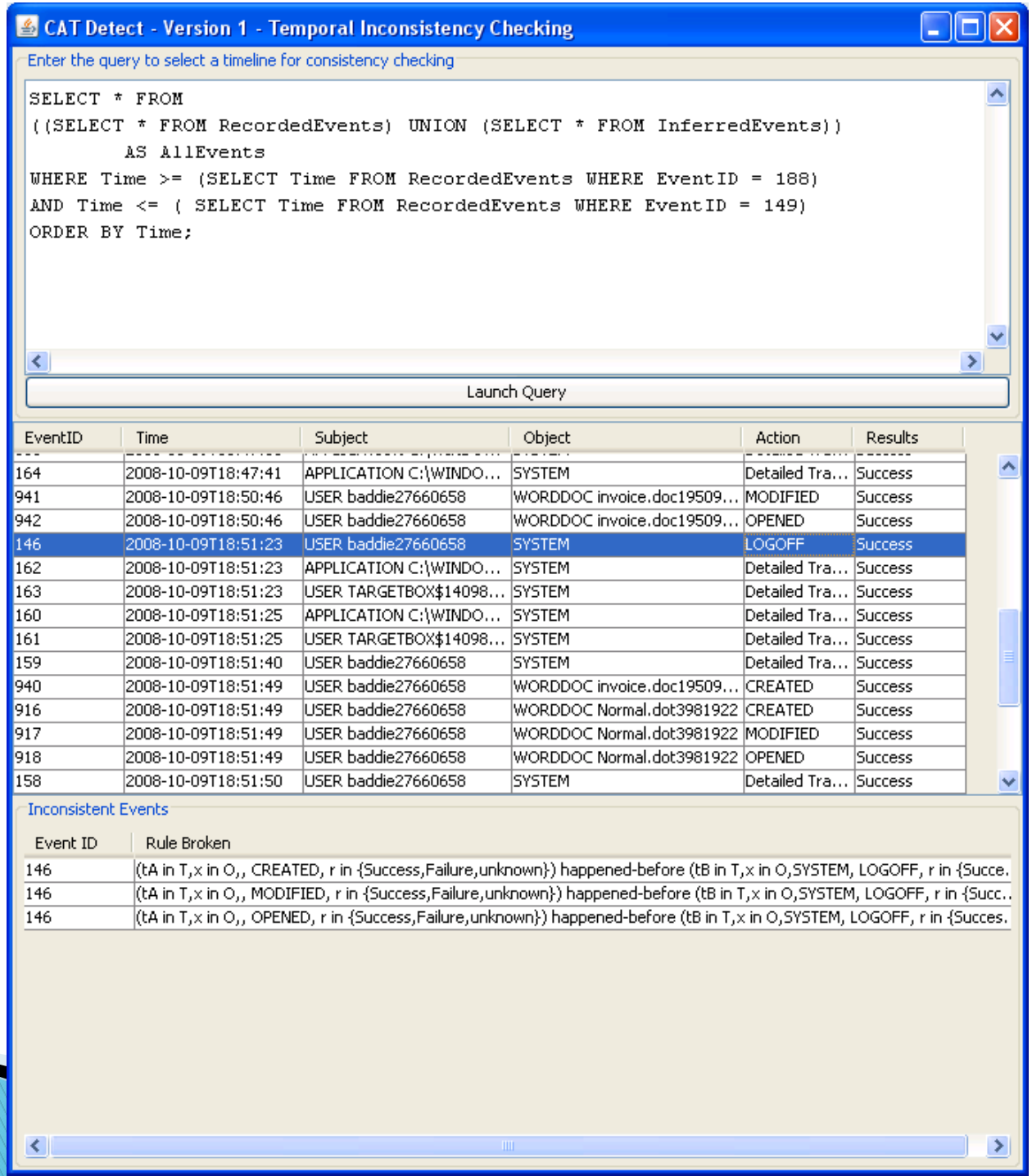
179 2008-10-09T18:47:14 APPLICATION C:\WINDOWS\system32\winlogon.exe30836417 SYSTEM Detailed Tra... Suc
180 2008-10-09T18:47:14 APPLICATION C:\WINDOWS\system32\userinit.exe16886931 SYSTEM Detailed Tra... Suc
181 2008-10-09T18:47:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Suc
182 2008-10-09T18:47:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Suc
183 2008-10-09T18:47:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Suc
184 2008-10-09T18:47:14 USER TARGETBOX$14098944 SYSTEM Privilege Use Suc
173 2008-10-09T18:47:15 APPLICATION C:\WINDOWS\system32\svchost.exe28732166 SYSTEM System Event Suc
174 2008-10-09T18:47:15 USER Domain:40717 SYSTEM Logon/Logoff Suc
175 2008-10-09T18:47:15 APPLICATION C:\WINDOWS\system32\svchost.exe28732166 SYSTEM System Event Suc
170 2008-10-09T18:47:16 APPLICATION C:\WINDOWS\system32\logonui.exe26903574 SYSTEM Detailed Tra... Suc
171 2008-10-09T18:47:16 APPLICATION Files\Messenger\msmsgs.exe29616570 SYSTEM Detailed Tra... Suc
Inconsistent Events
Event ID Rule Broken
940 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, CREATED, r in {Success,Failure,unknown}) && pre
916 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, CREATED, r in {Success,Failure,unknown}) && pre
917 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, MODIFIED, r in {Success,Failure,unknown}) && pr
941 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, MODIFIED, r in {Success,Failure,unknown}) && pr
918 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, OPENED, r in {Success,Failure,unknown}) && prec
942 (tA in T,x in O,SYSTEM, LOGON, Success) happened-before (tB in T,x in O,, OPENED, r in {Success,Failure,unknown}) && prec

Timeline D

- Query:

```
SELECT * FROM
((SELECT * FROM RecordedEvents) UNION
  (SELECT * FROM InferredEvents))
  AS AllEvents
WHERE Time >= (SELECT Time FROM
  RecordedEvents WHERE EventID = 188)
AND Time <= ( SELECT Time FROM
  RecordedEvents WHERE EventID = 149)
ORDER BY Time;
```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AS AllEvents
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AND Time <= (SELECT Time FROM RecordedEvents WHERE EventID = 149)
ORDER BY Time;
Launch Query
EventID Time Subject Object Action Results
164 2008-10-09T18:47:41 APPLICATION C:\WINDO... SYSTEM Detailed Tra... Success
941 2008-10-09T18:50:46 USER baddie27660658 WORDDOC invoice.doc19509... MODIFIED Success
942 2008-10-09T18:50:46 USER baddie27660658 WORDDOC invoice.doc19509... OPENED Success
146 2008-10-09T18:51:23 USER baddie27660658 SYSTEM LOGOFF Success
162 2008-10-09T18:51:23 APPLICATION C:\WINDO... SYSTEM Detailed Tra... Success
163 2008-10-09T18:51:23 USER TARGETBOX$14098... SYSTEM Detailed Tra... Success
160 2008-10-09T18:51:25 APPLICATION C:\WINDO... SYSTEM Detailed Tra... Success
161 2008-10-09T18:51:25 USER TARGETBOX$14098... SYSTEM Detailed Tra... Success
159 2008-10-09T18:51:40 USER baddie27660658 SYSTEM Detailed Tra... Success
940 2008-10-09T18:51:49 USER baddie27660658 WORDDOC invoice.doc19509... CREATED Success
916 2008-10-09T18:51:49 USER baddie27660658 WORDDOC Normal.dot3981922 CREATED Success
917 2008-10-09T18:51:49 USER baddie27660658 WORDDOC Normal.dot3981922 MODIFIED Success
918 2008-10-09T18:51:49 USER baddie27660658 WORDDOC Normal.dot3981922 OPENED Success
158 2008-10-09T18:51:50 USER baddie27660658 SYSTEM Detailed Tra... Success
Inconsistent Events
Event ID Rule Broken
146 (tA in T,x in O,, CREATED, r in {Success,Failure,unknown}) happened-before (tB in T,x in O,SYSTEM, LOGOFF, r in {Succe.
146 (tA in T,x in O,, MODIFIED, r in {Success,Failure,unknown}) happened-before (tB in T,x in O,SYSTEM, LOGOFF, r in {Succ..
146 (tA in T,x in O,, OPENED, r in {Success,Failure,unknown}) happened-before (tB in T,x in O,SYSTEM, LOGOFF, r in {Succes.

CAT Detect

- DFRWS Release

CAT Detect

- The CAT Detect DFRWS release is available to download from SourceForge now:

http://sourceforge.net/projects/catdetect/files/

- You will need Java 6 and MySQL 5.5 or later to run CAT Detect.
- CAT Detect's source code is available under the Academic Free License.

Disclaimer

- This is not final, production-quality software.
- We have not released CAT Detect because it is perfect – but rather, because it is far from perfect.
  - A to do list will be posted on the SourceForge list soon!
- If you are interested in contributing your ideas and effort to developing tools to detect inconsistencies in timelines, any input would be welcome.

Future Work

- Dynamic rules specification.
- Better parser integration (e.g. built-in Windows Event Log parser or close integration/front-end for GrokEVT or output).
- Automatic detection of user sessions.
- Obtain data sources and parsers to apply CAT Detect to non-Windows operating systems and newer versions of Windows.
- Fix some “unfortunate” user interface issues!