



A Visual Interface for Multivariate Temporal Data: Finding Patterns of Events across Multiple Histories

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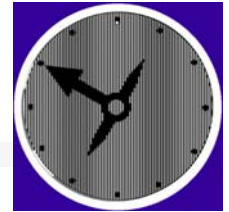
Human-Computer Interaction Lab &
Dept of Computer Science



UNIVERSITY OF
MARYLAND



Time is Pervasive!



- Stock market trades
- Web log URLs
- Medical histories
- Crime/terror activities
- Maintenance records



Add or Modify Your Bus Records

Bus Num: [] Vin Num: [FVRRVOCES45554555] Code: [A1234] Date: [06/02/95]

Maintenance Schedule to Use for this vehicle: [Schedule Four]

Year: [1995] License Num: [099564]

Location: [Lot] Key Num: [158]

Size: [55] Lift: [No] [No]

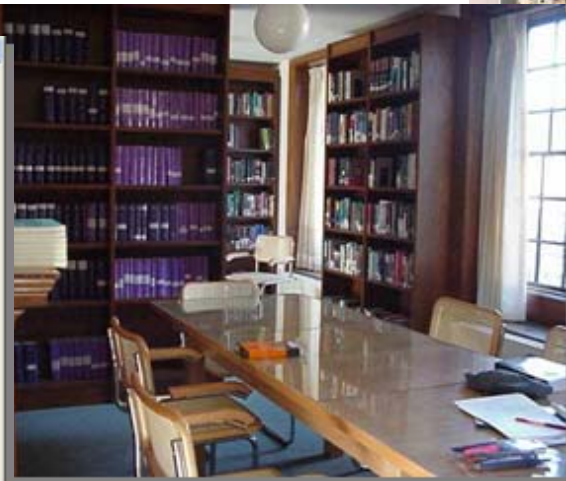
Model: [Bus] Make: [Blue] Body Make: [Freightliner]

Body Num: [50064] Air Brake: [Yes] Trans: [Manual]

Engine: [Diesel] OVR: []

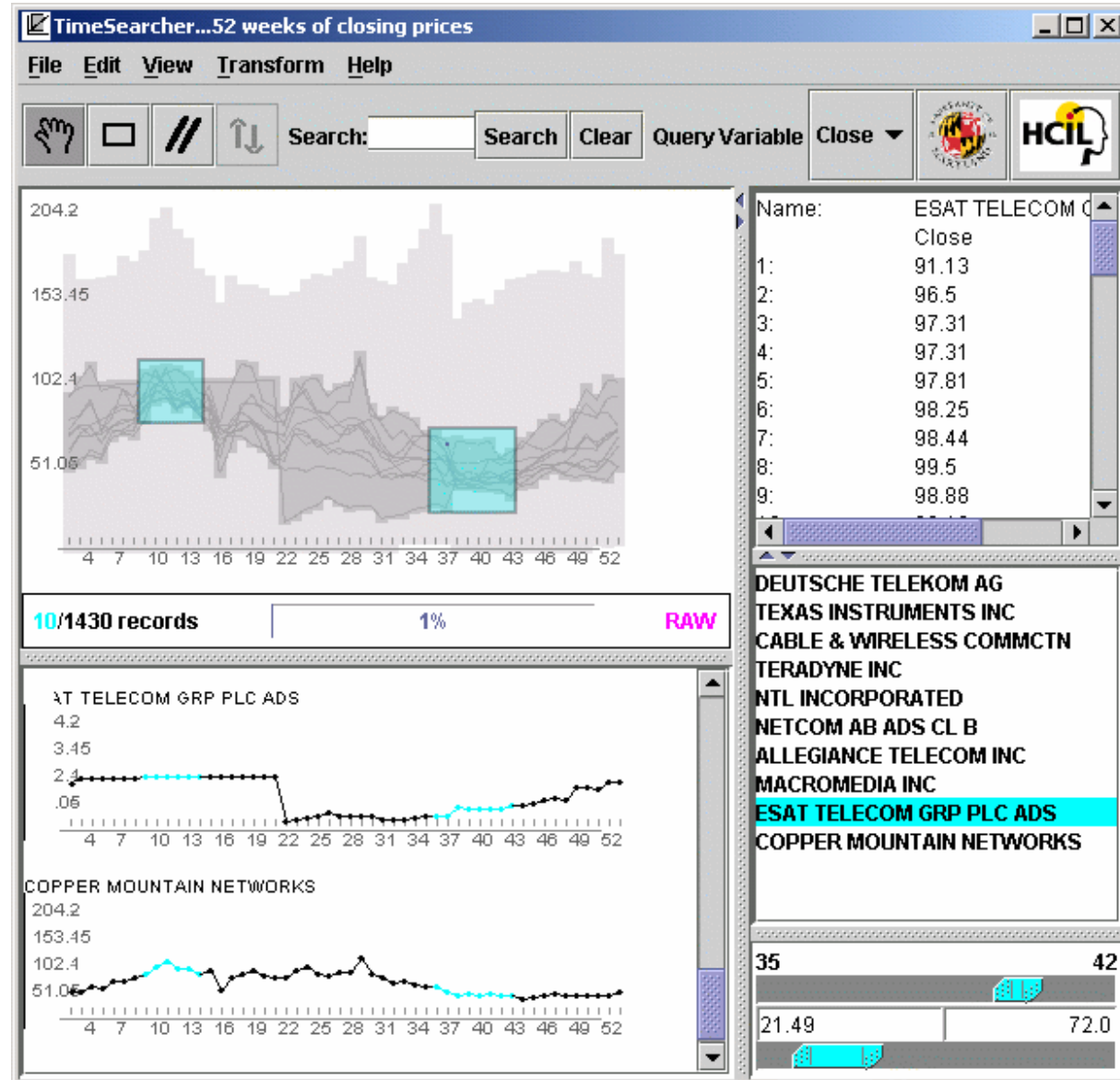
Print Bus Report

Use this navigation bar to change Vehicles.



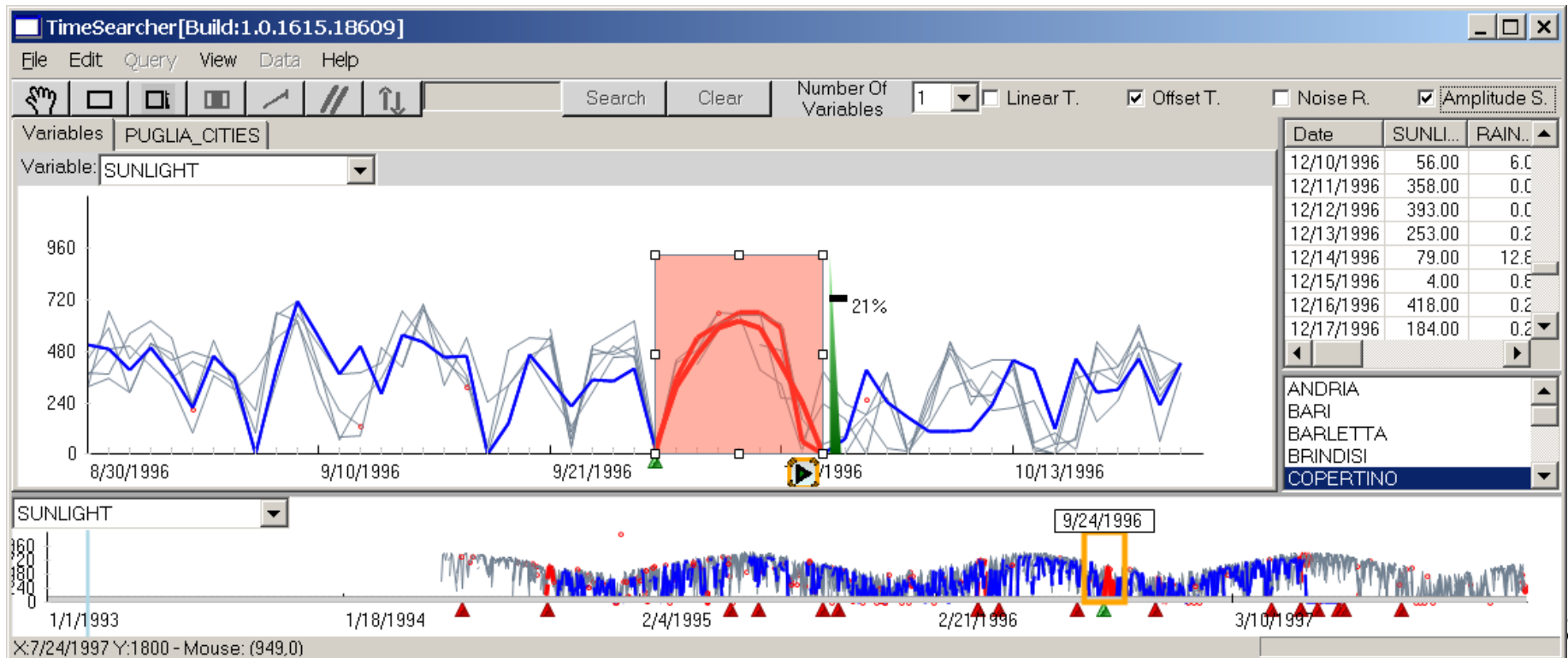
Temporal Data: TimeSearcher 1.3

- Time series
 - Stocks
 - Weather
 - Genes
- User-specified patterns
- Rapid search



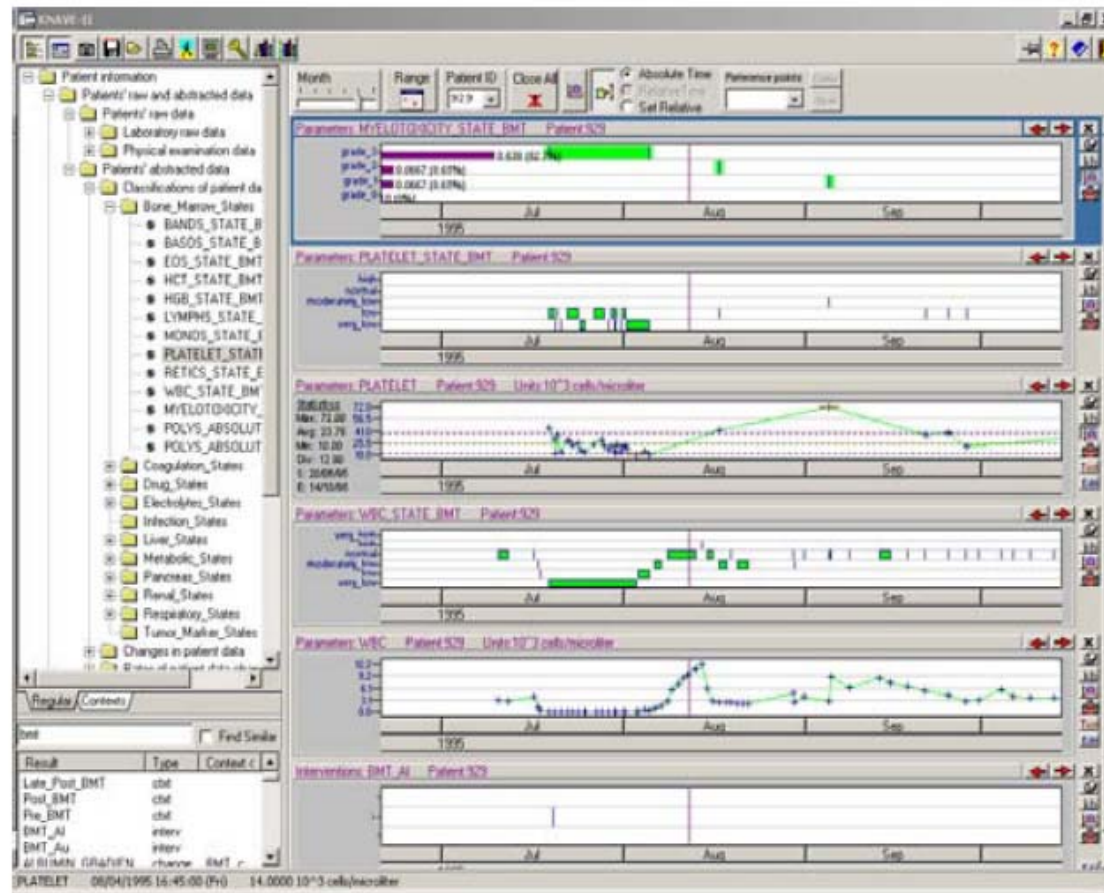
Temporal Data: TimeSearcher 2.0

- Long Time series (>10,000 time points)
- Multiple variables
- Controlled precision in match
(Linear, offset, noise, amplitude)



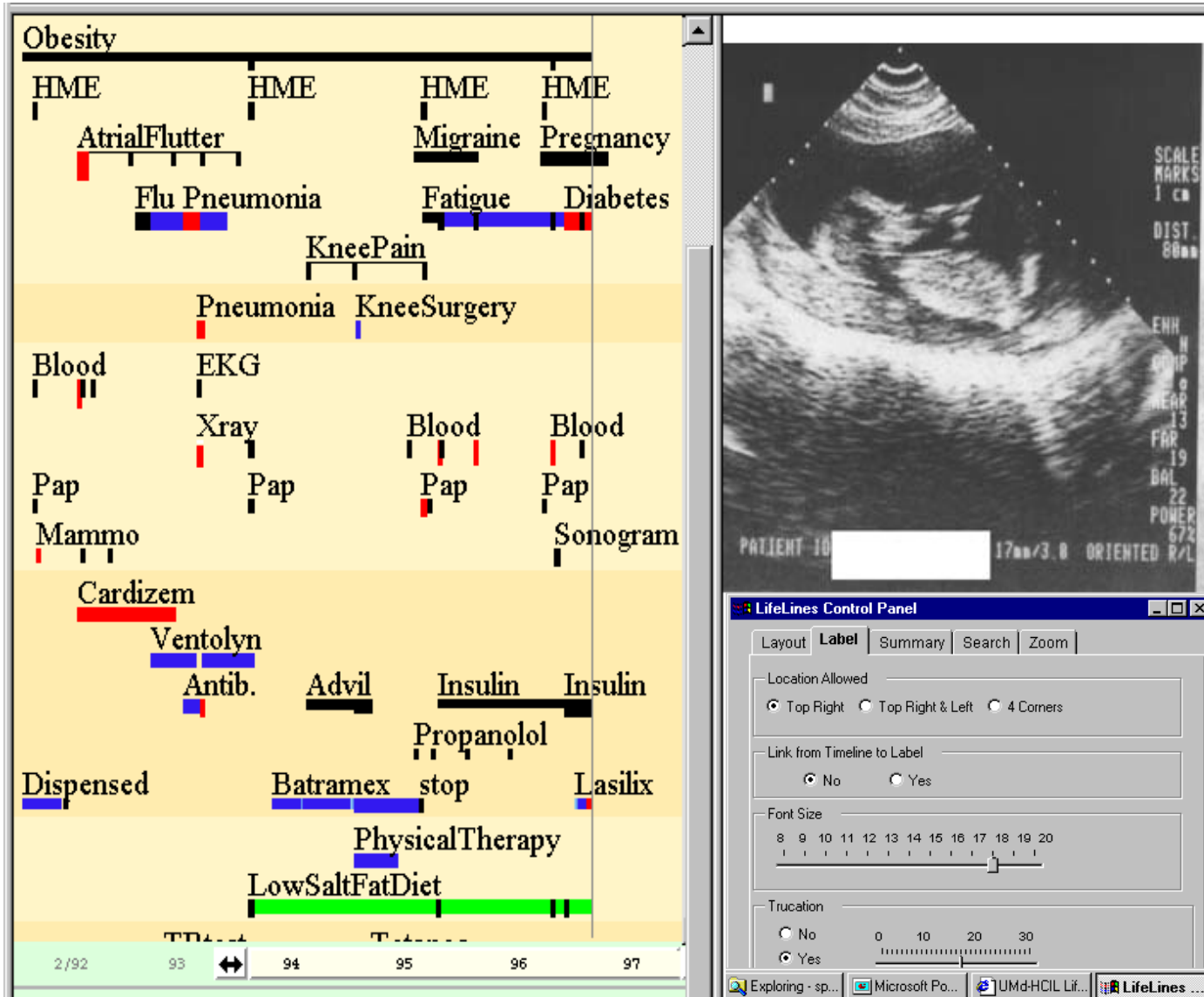
KNAVE: Clinical Patient Data

Distributed Knowledge-Based Abstraction, Visualization, and Exploration of Time-Oriented Clinical Data



(Shahar, 1998)

LifeLines: Visualizing Personal Histories



(Plaisant et al., CHI 1997)

Finding Patterns in Temporal Events

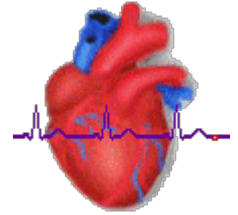
- Types of Time Data
 - Ordinal Values (e.g., TimeSearcher)
 - Categorical Events & Intervals (e.g., LifeLines)
 - Categorical Events
- Goal: Find Temporal Patterns
Across Millions of Records
 - SQL makes it very difficult to specify
 - Temporal SQL helps only a little

Comparison with SQL

```
SELECT P.*
FROM Person P, Event E1, Event E2, Event E3, Event E4

WHERE P.PID = E1.PID
  AND P.PID = E2.PID
  AND P.PID = E3.PID
  AND P.PID = E4.PID
  AND E1.type = "Medication"
  AND E1.class = "Anti Depressant"
  AND E1.name = "Remeron"
  AND E2.type = "Medication"
  AND E2.class = "Anti Depressant"
  AND E2.name = "Remeron"
  AND E3.type = "Medication"
  AND E3.class = "Anti Depressant"
  AND E3.name = "Remeron"
  AND E2.value > E1.value
  AND E3.value >= E2.value
  AND E2.date > E1.date
  AND E3.date >= E2.date
  AND E4.type = "Visit"
  AND E4.class = "Hospital"
  AND E4.name = "Emergency"
  AND E4.value = "Heart Attack"
  AND E4.date >= E3.date
  AND 180 <= (E4.date - E3.date)
```


Temporal Patterns in Medical Histories



- Reality
 - Very large & complex data sets
 - Missing, uncertain, and redundant data
- Tasks
 - Alerts concerning patient status
 - Decision support for treatment decisions
 - Clinical research on outcomes
 - Identify groups of patients for testing

Temporal Patterns in Medical Histories

	A	B	C	D	E
100					
101		Visits and Hospitalizations			
102		Date	Doctor	Location	Reason
103		1/16/2004	Kakani, Indira	Clinic	Follow up
104		11/15/2003	Kakani, Indira	Office	Follow up
105		10/15/2003	Carmichel, John	Hospital	Mastectomy
106		9/20/2003	Kakani, Indira	Hospital	Chemo treatment and mammogram
107		8/31/2003	Kakani, Indira	Hospital	Chemo Treatment
108		8/15/2003	Kakani, Indira	Hospital	Chemo Treatment
109		7/31/2003	Kakani, Indira	Clinic	Felt lump during breast exam
110		6/15/2001	Kakani, Indira	Clinic	Annual exam
111		1/12/2000	Kakani, Indira	Office	Annual exam
112		5/11/1999	Whitter, Herbert	Clinic	allergies kicking in
113		9/29/1997	Kakani, Indira	Office	Followup
114		8/17/1997	Kakani, Indira	Hospital	St. Thomas: Baby arrived
115		8/15/1997	Kakani, Indira	Office	final?? prenatal visit
116		8/8/1997	Kakani, Indira	Office	checkup
117		8/1/1997	Kakani, Indira	Office	reg checkup
118		7/21/1997	Kakani, Indira	Office	Beginning every two weeks
119		7/7/1997	Kakani, Indira	Office	regular checkup
120		6/21/1997	Kakani, Indira	Office	Standard checkup
121		6/1/1997	Kakani, Indira	Clinic	Ultrasound Followup
122		5/23/1997	Jones, Sam	Office	Check on high fever
123		5/22/1997	Kakani, Indira	Office	Regular checkup
124		4/10/1997	Kakani, Indira	Office	Regular checkup
125		2/23/1997	Kakani, Indira	Office	Visit for ultrasound
126		1/15/1997	Kakani, Indira	Office	Went to confirm pregnancy
127					

Ready



Finding Patterns in Temporal Events

- Imagine simple table

P-ID	Age	Gender	Date	Source	Attribute	Value
174	73	M	5/6/2005	Test	WBC	12
183	67	F	5/7/2005	ER	Symptom	Chest Pain
183	67	F	5/8/2005	Test	WBC	23
174	73	M	5/12/2005	Medication	Tylenol	325mg
259	71	F	5/12/2005	Test	HDL	55
174	73	M	5/14/2005	Test	WBC	19

Finding Patterns in Temporal Events

- Imagine an even simpler table

P-ID	Age	Gender	Date	Source	Attribute	Value
174	73	M	5/6/2005	Test	WBC	12
183	67	F	5/7/2005	Test	WBC	14
183	67	F	5/8/2005	Test	WBC	23
174	73	M	5/12/2005	Test	RBC	4
259	71	F	5/12/2005	Test	HDL	55
174	73	M	5/14/2005	Test	WBC	19

Person/People

Name

Age

Gender

Female

Male

People Selected: 950 of 950

Event Box 1

Type

Level 1

Level 2

Level 3

Value

Span (in days)

0 → 30

Event Box 2

Type

Level 1

Level 2

Level 3

Value

Span (in days)

1 → 30

Event Box 3

Type

Level 1

Level 2

Level 3

Value

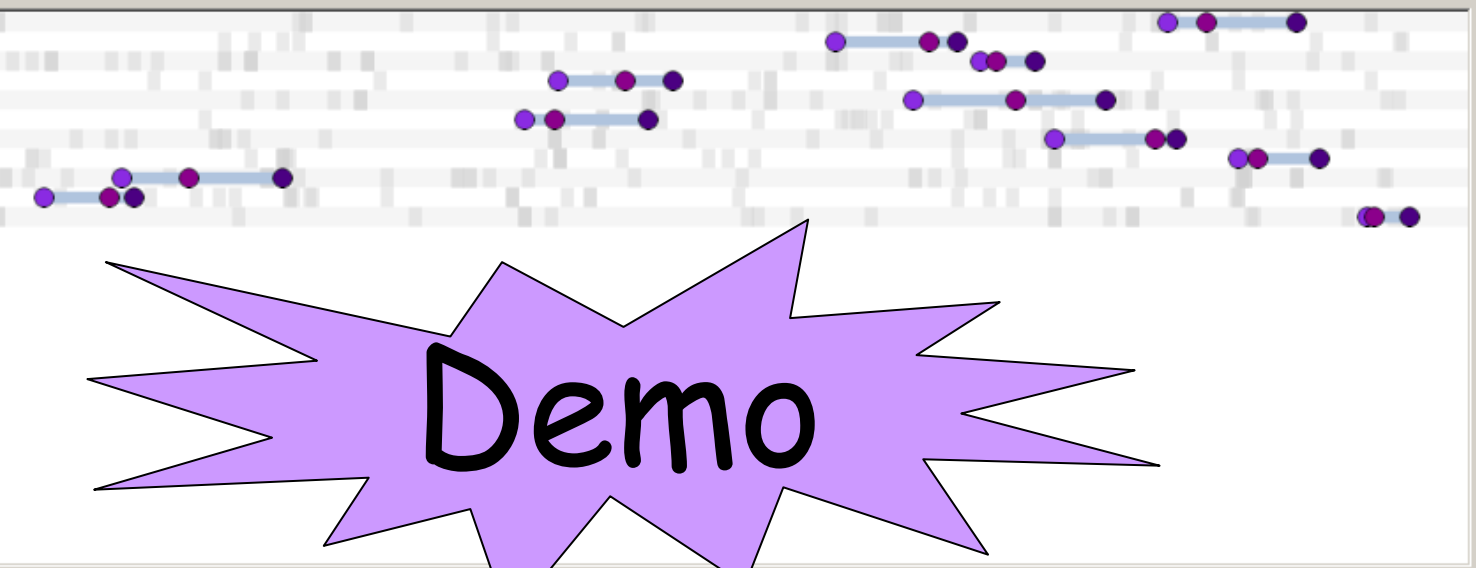
Span (in days)

1 → 30

01-Jan-2005 Min Date Span of 363 days Max Date

Visualization Table 11 matches found

- Bauerle, Marius
- Driggers, Janie
- Erskine, Sonny
- Iseman, Rolo
- Lacon, Kemp
- Reiss, Davie
- Siegrist, Verity
- Swartzbaugh, Warner
- Warren, Fredrick
- Wile, Matilda
- Williamson, Indiana



Show All Events

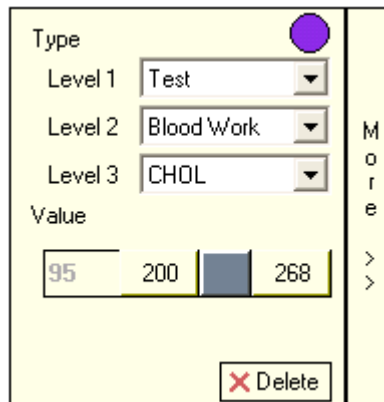
01-Jan-2005

30-Dec-2005

Simple Search: Event (E)

- No TimeSpan

**Find patients who
had cholesterol test
above 200**



The screenshot shows a search configuration window with the following elements:

- Type:** A purple circle icon.
- Level 1:** A dropdown menu with "Test" selected.
- Level 2:** A dropdown menu with "Blood Work" selected.
- Level 3:** A dropdown menu with "CHOL" selected.
- Value:** A range selector with a box containing "95", a vertical line at "200", a shaded area between "200" and "268", and a box containing "268".
- Buttons:** A "Delete" button with a red 'X' icon, and a vertical column of three right-pointing chevron symbols (>).

Simple Search: Two Events (E)

- No TimeSpan

Find patients who
had cholesterol test
above 200

And White Blood Cell
above 10

The diagram illustrates two search criteria connected by a logical AND operator. The first criterion is for a cholesterol test (CHOL) with a value above 200. The second criterion is for a White Blood Cell (WBC) test with a value above 10. A 'Span' checkbox is present between them, and a 'Days' time unit is selected.

Field	Value
Level 1	Test
Level 2	Blood Work
Level 3	CHOL
Value	95 200 268

Span

Minutes
Hours
Days
Weeks

Field	Value
Level 1	Test
Level 2	Blood Work
Level 3	WBC
Value	- 10 93

Events with Fixed Time (E-FT)

- Fixed TimeSpan length

Find patients who had cholesterol test above 200

And White Blood Cell above 10 exactly 1 day later

The screenshot shows a query builder interface with two criteria panels. The left panel is for a cholesterol test (CHOL) with a value range of 95 to 268. The right panel is for a White Blood Cell test (WBC) with a value range of 10 to 93. Both panels have a 'Span' dropdown menu set to 'Days' and a value of '1'. An orange box highlights the 'Span' dropdown and the '1' value field for the first criterion.

Criteria	Type	Level 1	Level 2	Level 3	Value Range	Span	Span Value
1	Test	Blood Work	CHOL		95 - 268	Days	1
2	Test	Blood Work	WBC		10 - 93	Days	1

Events with Variable Time (E-VT)

- Variable TimeSpan length

Find patients who had cholesterol test above 200

And White Blood Cell above 10 with 0 to 7 days later

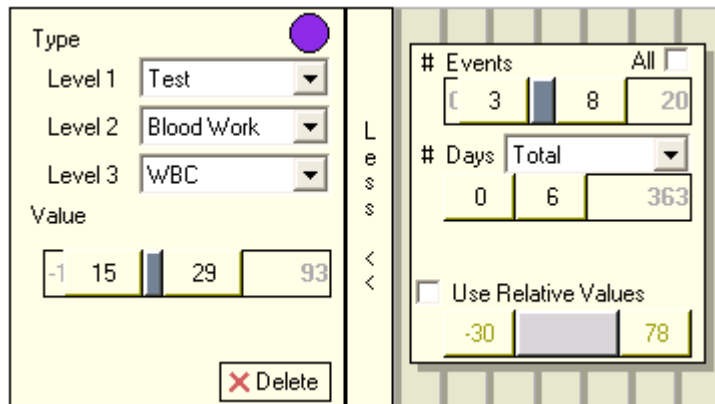
The screenshot shows a query builder interface with two criteria. The first criterion is for a cholesterol test (CHOL) with a value range of 200 to 268. The second criterion is for a White Blood Cell (WBC) test with a value range of 10 to 93 and a time span of 0 to 7 days. An orange box highlights the 'Days' unit and the '0' start value in the time span field.

Criteria	Level 1	Level 2	Level 3	Value Range	Time Span
Cholesterol Test	Test	Blood Work	CHOL	200 - 268	0 - 7 Days
White Blood Cell Test	Test	Blood Work	WBC	10 - 93	0 - 7 Days

Trends with Event Sets E*WC

- Sets of Events behave as single Events
- Adds Window and Cardinality constraints

Find patients with 3-8
WBC tests at 15-29,
during a 6 day period



PatternFinder Interface

The screenshot displays the TempViz PatternFinder interface, which is used for defining temporal patterns. The interface is divided into several sections:

- Person/People:** A sidebar on the left for filtering individuals. It includes a Name dropdown, an Age range slider (set to 4 to 78), and Gender checkboxes (Female and Male are selected). It shows "People Selected: 6 of 950".
- Event Box 1:** A central configuration box for the first event. It has a purple circle icon. The Type is "Medications". Level 1 is "Medications", Level 2 is "Anti Depressan", and Level 3 is "Remeron". The Value is a range slider set from 4 to 126. A "Use Relative Values" checkbox is checked. The # Events range is 2 to 20, and the # Days range is 0 to 363. A "Delete" button is at the bottom.
- Event Box 2:** A central configuration box for the second event. It has a pink circle icon. The Type is "Heart Attack". Level 1 is "Visit", Level 2 is "Hospital", and Level 3 is "Emergency". The Value is a list of conditions: "Auto Accident", "Bone Fracture", "Heart Attack" (checked), and "Kidney Stone". A "Delete" button is at the bottom.
- Span:** A section between the event boxes with a "Span" checkbox checked and a unit selector (Minutes, Hours, Days, Weeks) set to "Days". A blue arrow indicates a span of 180 days between the two event boxes.
- Timeline:** A bar at the bottom shows the date range from "01-Jan-2005" (Min Date) to "30-Dec-2005" (Max Date) with a "Span of 363 days".
- Buttons:** A "Run Query" button is located at the bottom center, and an "Add Constraint" button is on the right side.

This pattern specifies any patient who received increasing dosages of Remeron followed by a heart attack within 180 days (along with the events constituting the temporal pattern match).

Current work

Work with Washington Hospital Center

- Developing taxonomy of simple queries
- Designing interface to fit in Azyxxi
- Implementing simple searches

Lab value [HGB] is high, then decreases >1.5

Lab value [Platelets] is high in a patient on heparin, then decreases $> 20\%$

Patient seen at ER & discharged, then returns to ER within 14 days

Patient seen at ER & discharged, then returns to ER within 14 days & condition = [dead]

Diverse Applications

Maintenance log

Replace battery, repair generator, repair starter,...

Web log analysis

Browse books, Checkout, Help, Leave Website

Terror/criminal behavior

Withdraw funds, buy weapon, purchase tickets...

TV viewing (in 30 min segments)

NBC, ABC, ABC, ABC, CBS, CBS

Contributions: Queries for temporal events

- Taxonomy of queries
- Visual specification
- Visualization of results: ball & chain view

Contributions: Queries for temporal events

- Taxonomy of queries
- Visual specification
- Visualization of results: ball & chain view
- Reformulation of relational completeness
- Facilitate medical treatment & research



24th Annual Symposium
May 31-June 1, 2007

www.cs.umd.edu/hcil

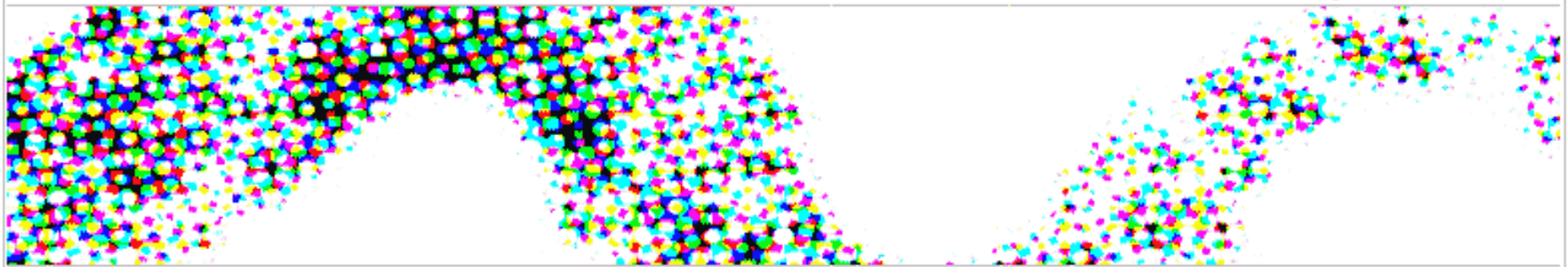


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...practice. Rigorous research is
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Important Dates

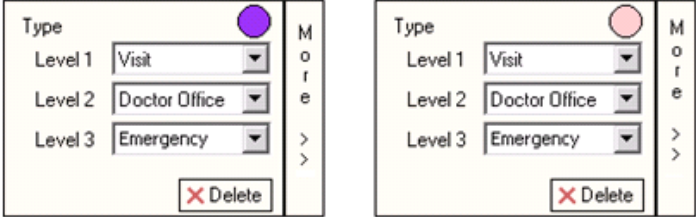
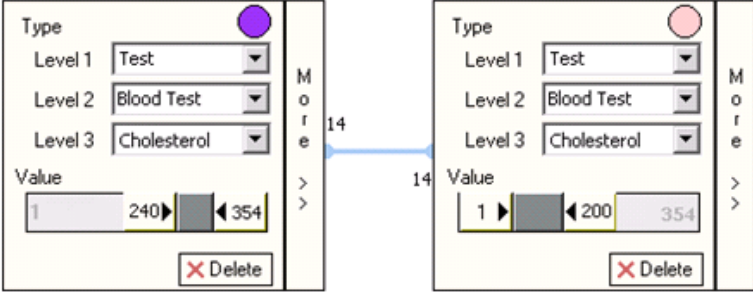
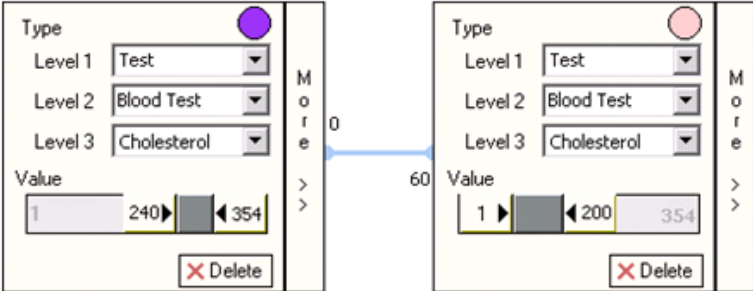
Papers Deadline:	December 15, 2006
Notification:	February 19, 2007
Revised papers:	March 19, 2007
Conference:	June 13-15, 2007

<http://www.cs.umd.edu/hcil/CC2007/>

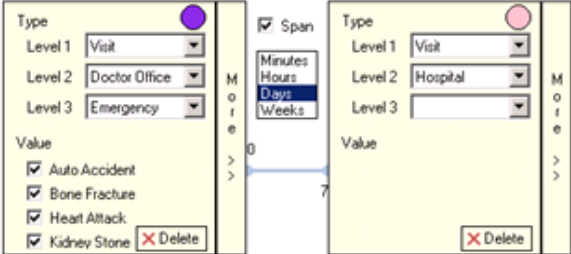
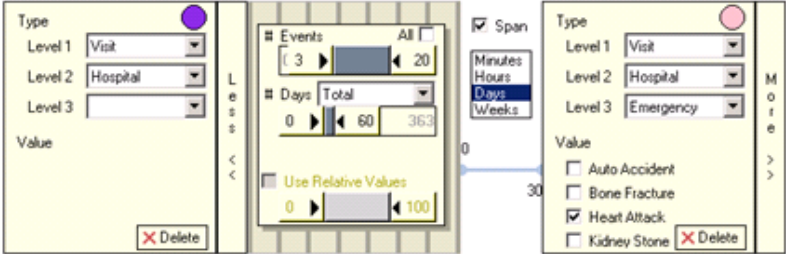
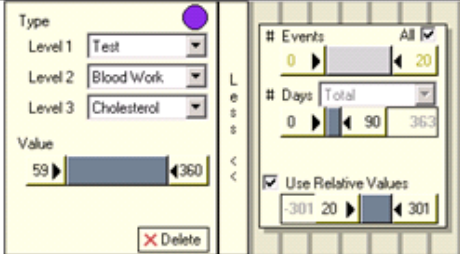
...re two elegant evening receptions at
...DC locations:

...the National Academy of Sciences (June 13) and Corcoran Gallery of Art (June 14)

Taxonomy Table (1 of 2)

Pattern	Restrictions	Example
<p style="text-align: center;">E Events Only</p>	<p>Event: Specify all non-temporal attributes of one or more events.</p> <p>TimeSpan: No span. Left to right ordering implicitly denotes “any time later”.</p>	 <p style="text-align: center;">Find patients who have had at least 2 emergency doctor visits.</p>
<p style="text-align: center;">E-FT Fixed TimeSpans</p>	<p>Event: Specify all non-temporal attributes of <i>two or more events</i>.</p> <p>TimeSpan: Relative <u>TimeSpan</u> of <u>fixed size</u>.</p>	 <p style="text-align: center;">Find patients whose cholesterol was above 240 but two weeks later was below 200.</p>
<p style="text-align: center;">E-VT Variable TimeSpans</p>	<p>Events: Same as E-FT.</p> <p>TimeSpan: Relative <u>TimeSpan</u> of <u>variable size</u>.</p>	 <p style="text-align: center;">Find patients whose cholesterol was above 240 but fell below 200 within 2 months.</p>

Taxonomy Table (2 of 2)

Pattern	Restrictions	Example
<p>E*-VT Variable Events Variable TimeSpans</p>	<p>Event: Specify a <i>subset</i> of non-temporal attributes of one or more events.</p> <p>TimeSpan: Same as E-VT</p>	 <p>Find patients who had an emergency doctor's visit followed by a hospitalization within a week.</p>
<p>E*WC-VT Linked EventSet and Event</p>	<p>Event: Specify a subset of non-temporal attributes of one or more event <i>sets</i>. The elements of an event set are defined by a relative time <i>window</i> during which all events in the set must occur, as well as <i>cardinality</i> - the number of events that must occur within the window.</p> <p>TimeSpan: Same as E-VT.</p>	 <p>Find patients who had 3 or more hospitalizations within two months followed by a heart attack hospitalization within a month.</p>
<p>f(E*WC)-VT EventSet</p>	<p>Event: Same as E*WC-VT plus a functional condition that must hold across all members of the set.</p> <p>TimeSpan: Same as E-VT</p>	 <p>Find patients whose cholesterol increased by at least 20 points each reading for 3 months.</p>

Current work

Query 1: Fixed patient values and fixed dates

Low HGB followed by higher HGB after 9/22/2006

Filter1: HGB < 150 Date < 9/22/2006

Filter2: HGB > 160 Date > 9/22/2006

Query 2: Fixed patient values and relative dates

Low HGB followed by higher HGB After the first reading.

Filter1: HGB < 150 Date < 9/22/2006

Filter2: HGB > 160 Date AFTER F1.Date

Query 3: Relative patient values and relative dates

Low HGB followed by HGB 5 points higher, After the first reading.

Filter1: HGB < 150 Date < 9/22/2006

Filter2: HGB > F1.HGB+5 Date AFTER F1.Date