Signal Processing on Databases

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Lecture 4: Analysis of Structured Data

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Outline

- **Introduction**
  - **Schema**
  - **Stats (Analytic 1)**
- **First Order Analytics**
- **Second Order Analytics**
- **Summary**

Generic D4M Triple Store Schema

Accumulo Table: Ttranspose

	01-01-2001	02-01-2001	03-01-2001
Col1|a	1		
Col1|b		1	
Col2|b		1	
Col2|c			1
Col3|a	1		
Col3|c			1

Input Data

Time	Col1	Col2	Col3
2001-01-01	a		a
2001-01-02	b	b	
2001-01-03		c	c

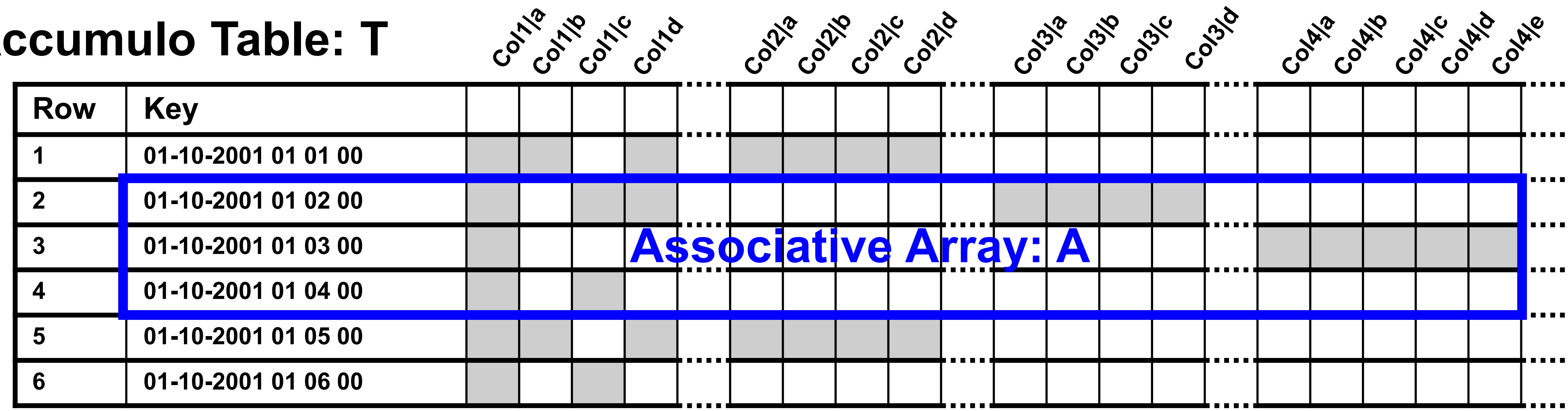
	Col1|a	Col1|b	Col2|b	Col2|c	Col3|a	Col3|c
01-01-2001	1				1	
02-01-2001		1	1			
03-01-2001				1		1

Accumulo Table: T

- Tabular data expanded to create many type/value columns
- Transpose pairs allows quick look up of either row or column
- Big endian time for parallel performance

Stats (Analytic 1) Diagram

Accumulo Table: T



- **Copy a set of rows from T into associative array A**
- **Perform the following statistical calculations on A**
  - **Column count: how many times each column appears in A**
  - **Column type count: how many times each column type appears in A**
  - **Column covariance: how many times each pair of columns in A appear in the same row together**
  - **Column covariance: how many times each pair of column types in A appear in the same row together**

- **Good for identifying column types, gaps, clutter, and correlations**

Stats Implementation

- **Define a set of rows**

r = '01-01-2001 01 02 00,01-01-2001 01 03 00,01-01-2001 01 04 00,'

- **Copy rows from table to associative array and convert** '1' **to** 1

A = dblLogi(T(r,:))

- **Compute column counts**

sum(A,1)

- **Compute column covariance**

A' * A **or** sqIn(A)

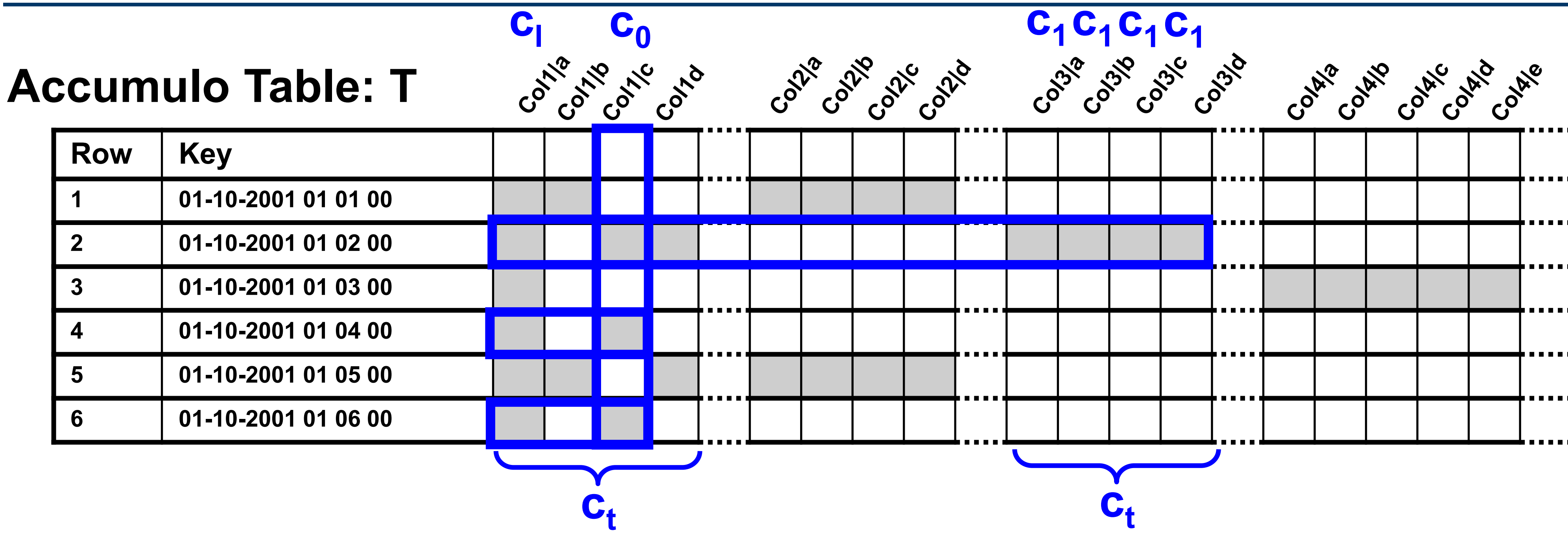
- **Compute column type counts and covariance by substituting**

A = col2type(A,'|');

Outline

- Introduction
- First Order Analytics
  - Data Graph (Analytic 2)
  - Space (Analytic 3)
  - Convolution (Analytic 4)
- Second Order Analytics
- Summary

Data Graphs (Analytic 2) Diagram



- Define data graph inputs
  - Start columns c_0
  - Allowed column types c_t
  - Clutter columns c_l
- Get all columns c_1 in rows containing c_0 of type c_t and excluding columns c_l

> - The fundamental operation upon which all graphs are built
> - Perform recursively to grow graph from starting columns

Data Graph Implementation

- **Define start columns, allowed column types and clutter**

  c0='Col1|c,' ct=StartsWith('Col1|,Col3|,') cl='Col1|a,'

- **Copy all columns from rows containing** c0 **into associative array**

  A = dblLogi(T(Row(T(:,c0)),:))

- **Reduce to allowed columns**

  A = A(:,ct)

- **Eliminate clutter columns and return column labels**

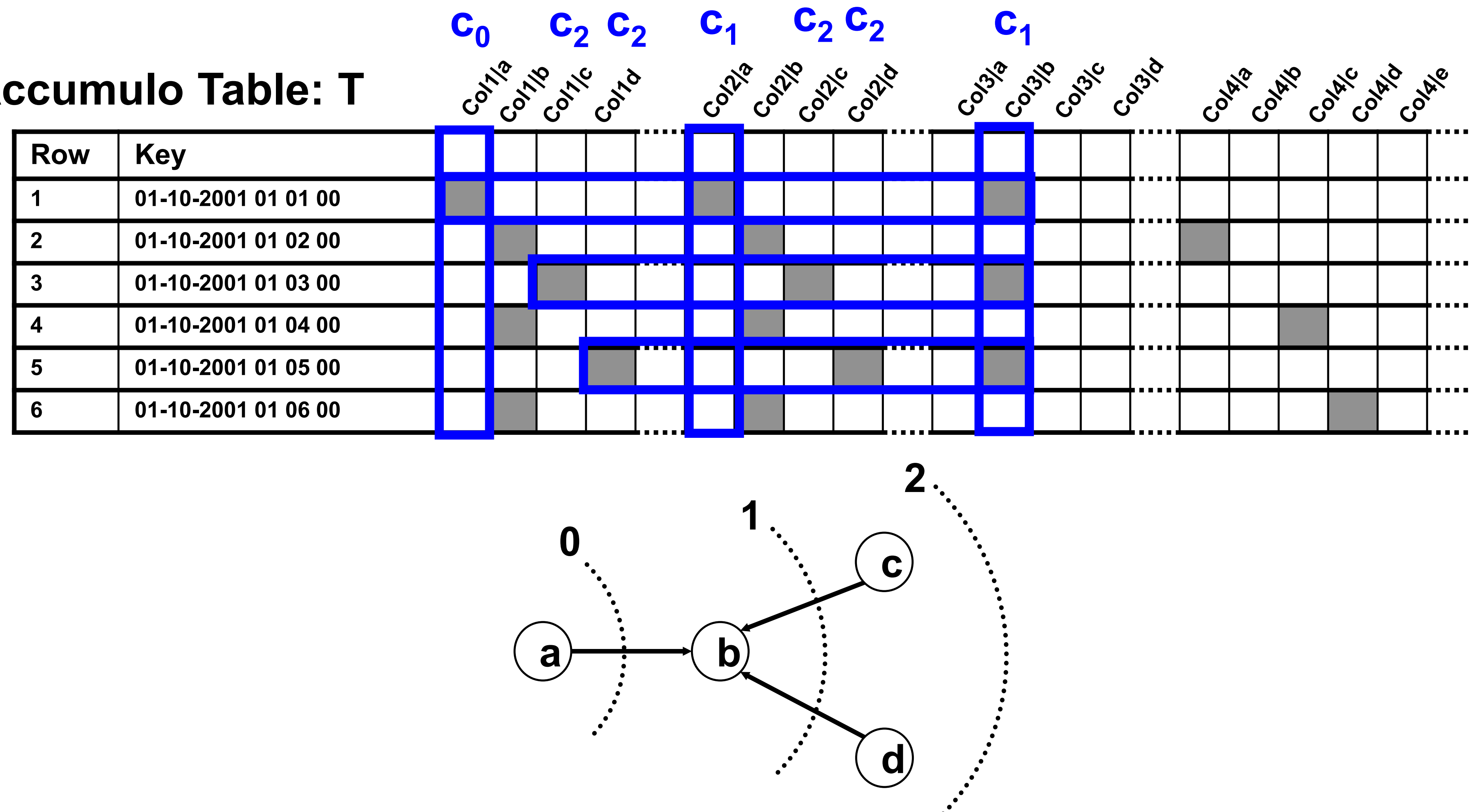
  c1 = Col(A - A(:,cl))

- **Look for new clutter**

  sum(dblLogi(T(:,c1)),1)) > 10

Data Graphs Example 1

Accumulo Table: T



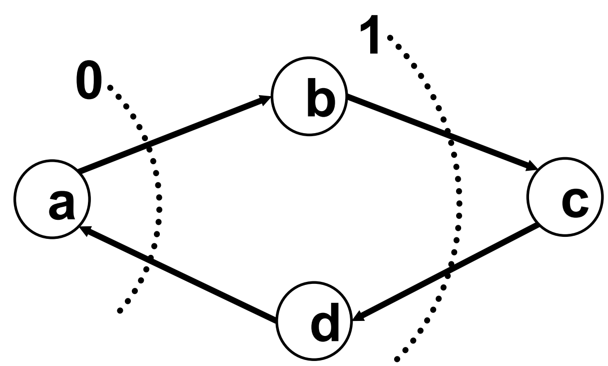
- Limited by the natural topology of the data
- Star data is good for generating star data graphs

Data Graphs Example 2

c_0 c_1 c_1 c_1

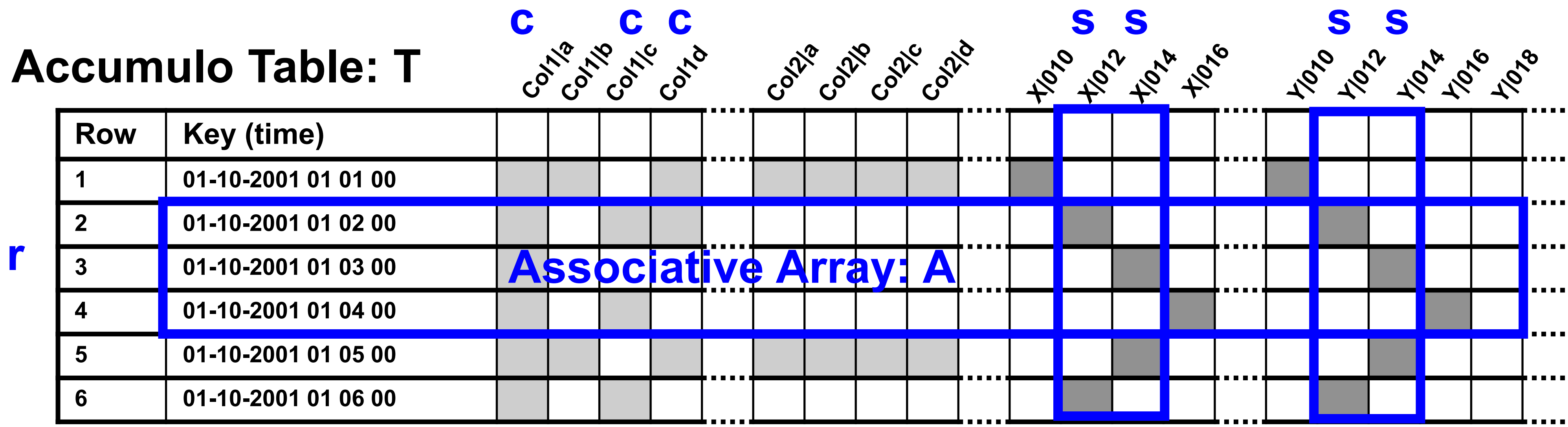
Accumulo Table: T

Row	Key	Col1|a	Col1|b	Col1|c	Col1d	Col2|a	Col2|b	Col2|c	Col2|d	Col3|a	Col3|b	Col3|c	Col3|d	Col4|a	Col4|b	Col4|c	Col4|d	Col4|e
1	01-10-2001 01 01 00																	
2	01-10-2001 01 02 00																	
3	01-10-2001 01 03 00																	
4	01-10-2001 01 04 00																	
5	01-10-2001 01 05 00																	
6	01-10-2001 01 06 00																	
7	01-10-2001 01 07 00																	
8	01-10-2001 01 08 00																	



- Limited by the natural topology of the data
- Star data is limiting for generating cycle data graphs

Space (Analytic 3) Diagram



- Select row range r and a space polygon s
- Copy a set of rows from T into associative array A
- Extract space coordinates from rows and determine if inside s
- Return columns c that satisfy these constraints

> - Good for finding columns in a particular space window
> - Can apply filter to space first is coordinates are “Mertonized”

Space Implementation

- **Define row range and space polygon**

```
r='01-01-2001 00 02 00,:,01-01-2001 00 04 00,'
s=complex([11 15 15 11 11],[15 15 11 11 15])
```

- **Copy all rows within** t **into associative array**

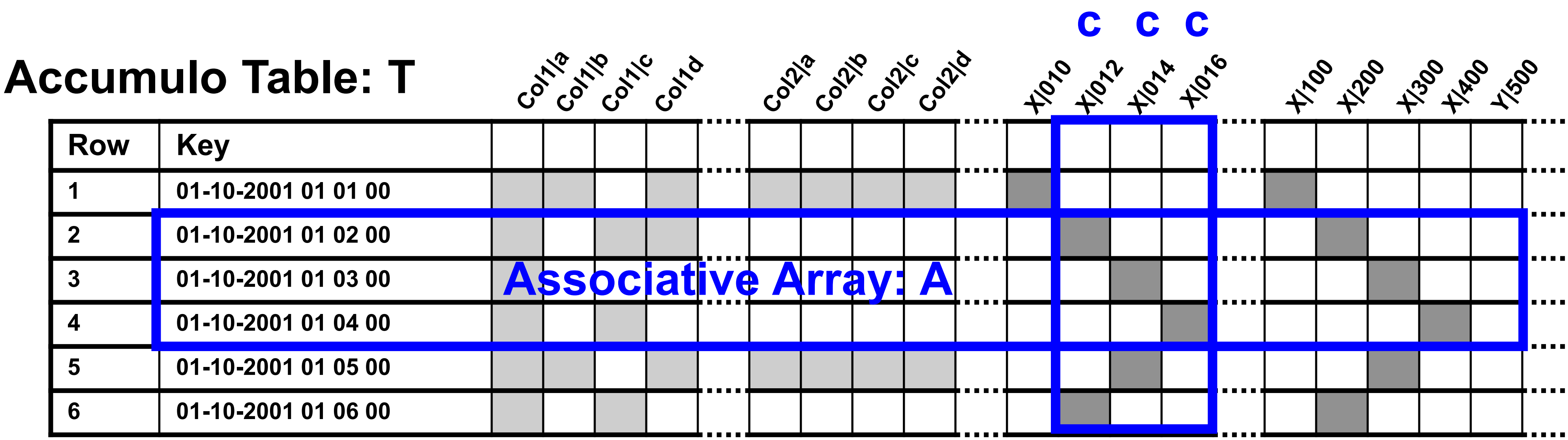
```
A = T(r,:)
```

- **Get coordinates**

```
Axy = str2num(col2type(A(:,StartsWith('X|,Y|,')),'|'))
```

- **Select columns in rows in space polygon**

```
inS = inpolygon(Adj(Axy(:,'X,')),Adj(Axy(:,'Y,')),
                real(s),imag(s))),:))
c = Col(A(find(inS),:))
```



Convolution (Analytic 4) Diagram

- Copy a set of rows from T into associative array A
- Select a numeric column type and convolve with a filter

- Standard signal processing technique for finding groups

Convolution Implementation

- **Define a set of rows and a filter of width 4**

```
r = '01-01-2001 01 02 00,01-01-2001 01 03 00,01-01-2001 01 04 00,'
f = ones(1,4)
```

- **Copy rows from table to associative array and convert** '1' **to** 1

```
A = dblLogi(T(r,:))
```

- **Create vector of numeric type rows**

```
Av = dblLogi(col2val(sum(A(:,StartsWith('X|,')),1)))
```

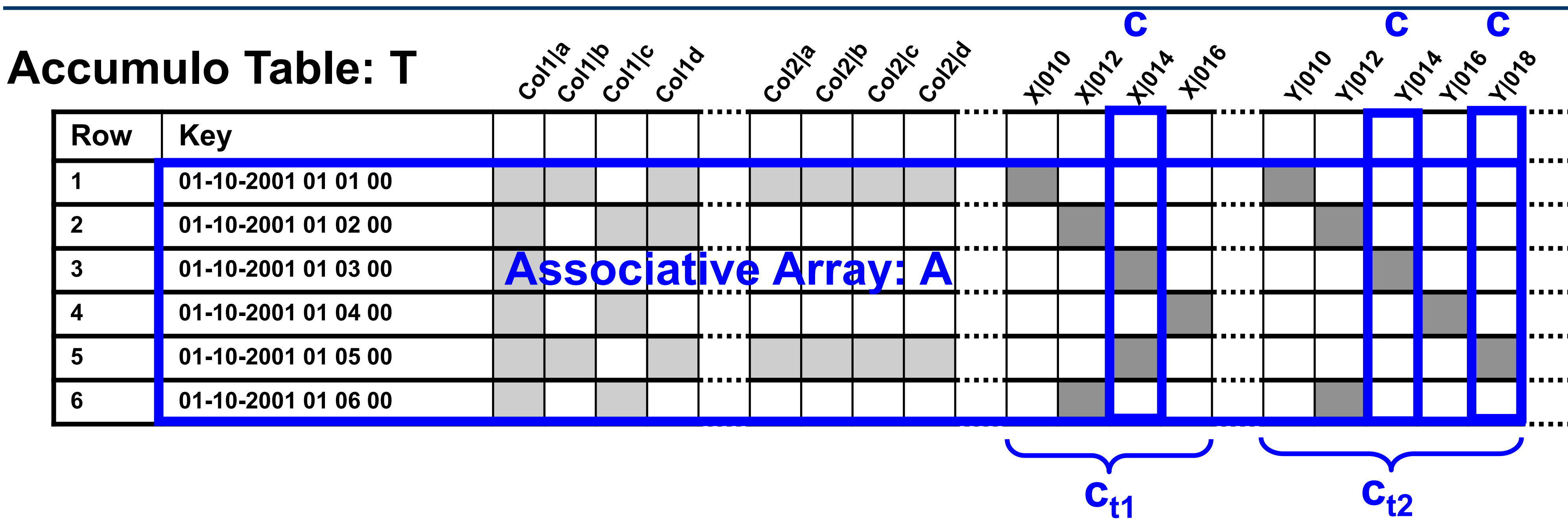
- **Convolve with filter and find columns > 1**

```
c = Col(conv(Av,f) > 1)
```

Outline

- Introduction
- First Order Analytics
- Second Order Analytics
  - Type Pair (Analytic 5)
  - Data Pair (Analytic 6)
  - Semantic Extension (Analytic 7)
  - Semantic Pair (Analytic 8)
- Summary

Type Pair (Analytic 5) Diagram



- Copy a set of rows from T into associative array A
- Find rows in A that contain both pair types c_{t1} and c_{t2}
- Find columns of each type are paired with more than one column of the other type

- Good for tracking columns that occur in pairs

Type Pair Implementation

- **Define row range and type pair**

```
r = '01-01-2001 00 01 00,:,01-01-2001 00 06 00,'
ct1 =     StartsWith('X|,')              ct2 = StartsWith('Y|,')
```

- **Copy rows from table to associative array and convert** '1' **to** 1

```
A = dblLogi(T(r,:))
```

- **Find rows containing both column types in the pair**

```
r = Row(sum(A(Row(sum(A(:,ct1),2)==1),[ct1 ct2]),2)==2);
```

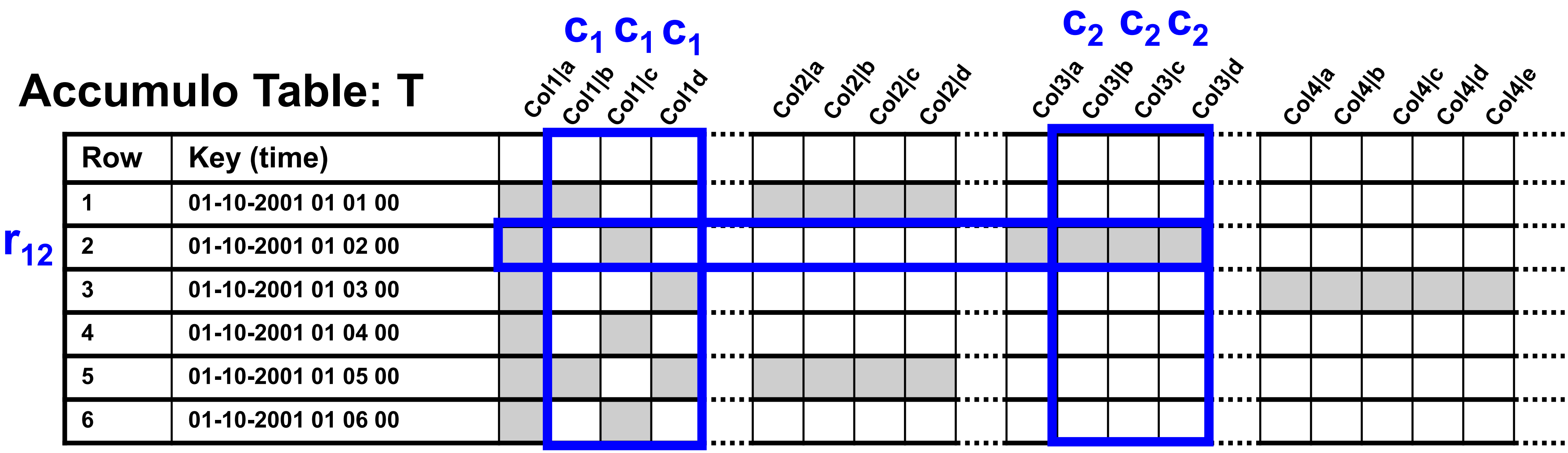
- **Get columns in order for creating a pair mapping matrix**

```
[tmp c1 tmp] = A(r,ct1)
[tmp c2 tmp] = A(r,ct2)
A12 = Assoc(c1,c2,1)
```

- **Find** ct1 **with more than one** ct2 **and vice versa**

```
sum(A12,1) > 1        sum(A12,2) > 1
```

Data Pair (Analytic 6) Diagram



- Define column pair sets c_1 and c_2
- Get all columns c_1 and c_2
- Find rows r_{12} that have one entry in c_1 and c_2

- **Checks to see if data pairs are present in the same row**

Data Pair Implementation

- **Define column pair sets**

```
c1  = 'Col1|b,Col1|c,Col1|d,'
c2  = 'Col3|b,Col3|c,Col3|d,'
c12 = CatStr(c1,';',c2)
```

- **Create pair mapping matrices**

```
A1p = Assoc(c1,c12,1)     A2p = Assoc(c2,c12,1)
```

- **Get columns from T**

```
A1 = dblLogi(T(:,c1))
A2 = dblLogi(T(:,c2))
```

- **Find pairs**

```
((A1*A1p) + (A2*A2p)) > 1)
```

Semantic Extension (Analytic 7)

- **Column types may have several types of semantic relationships which can be used to extend pairs**

- **Pair reversal**

  Example: pair 'Col1|a;Col3|b' **implies**'Col3|b;Col1|a'

- **Type extension.**

  Example: column 'Col1|a' **implies**'Col2|a'

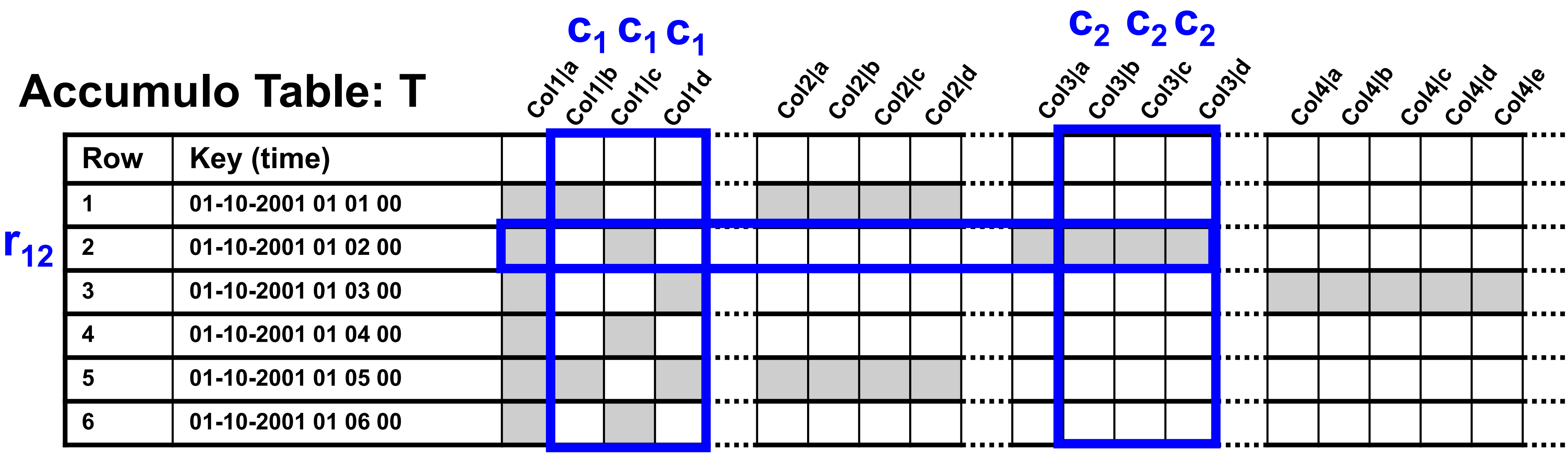
- **Data graph extension.**

  Example: column 'Col1|a' **implies**'Col2|b'**if** 'Col1|a' **and**'Col2|b'**appear in the same row**

- **Allows additional semantic data to be used to greatly increase the number columns that can be matched in a table**

Semantic Pair (Analytic 8) Diagram

Accumulo Table: T



- Define column pair sets c_1 and c_2
- Extend all columns via semantic information
- Get all columns c_1 and c_2
- Find rows r_{12} that have one entry in c_1 and c_2

- **Checks to see if semantic pairs are present in the same row**

Summary

- Exploded Schema allows rapid access to both rows and column
- Graph analytics can be implemented as a sequence of row and column queries
- Complex analytics can be implemented via matrix multiply

Example Code & Assignment

- Example Code (end of Lecture 3 and start of lecture 4)
  - d4m_api/examples/2Apps/1EntityAnalysis
  - d4m_api/examples/2Apps/2TrackAnalysis

- Assignment 3
  - For your associative arrays in Assignment 1 compute three different cross correlations using matrix multiply
  - Explain the meaning of each cross-correlation