TIME SERIES DATA
PAPERS COVERED

- Interactive Visualization of Serial Periodic Data
  - John V. Carlis and Joseph A. Konstan

- Visualizing and Discovering Non-Trivial Patterns in Large Time Series Databases
  - Jessica Lin, Eamonn Keogh, Stefano Lonardi

- Time-series Bitmaps: A Practical Visualization Tool for working with Large Time Series
  - Nitin Kumar, Nishanth Lolla, Eamonn Keogh, Stefano Lonardi, Chotirat Ann Ratanamahatana
WHAT IS TIME SERIES DATA?
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- A value over time
WHAT IS TIME SERIES DATA?

- A value over time
  - not too useful
- A sequence of time point + value pairs
  - $< t_0, v_0 >$
  - $< t_1, v_1 >$
  - $< t_2, v_2 >$
  - ...
  - $< t_n, v_n >$
**What is time series data?**

- $t_i \leq t_{i+1}$
  - not $t_i < t_{i+1}$
- Low resolution of time
- Errors
- Discontinuities
- Multiple sources of measurement
WHAT IS TIME SERIES DATA?

- common examples:
  - financial data
  - electrocardiograms
  - meteorological data
  - production rates
  - ...
WHAT IS TIME SERIES DATA?

- Doesn’t need to be a numerical value over time
  - routes
    - position over time
  - schedules
    - Activity over time (resource focused)
    - resource over time (activity focused)
Tasks with Time Series Data

- Finding patterns
  - periodic vs non-periodic
  - finding known patterns
    - searching
    - sequence matching
    - classification
  - finding common unknown patterns
    - motif discovery
    - clustering
  - finding rare patterns
    - anomaly detection
Tasks with time series data

- Finding trends
  - general increasing/decreasing
  - abrupt changes
    - anomaly detection
  - correlation between variables
Paper 1

- Interactive Visualization of Serial Periodic Data
  - John V. Carlis and Joseph A. Konstan
PERIODIC DATA

- “Pure” periodic data
  - each period has identical duration
- vs event anchored periodic data
  - periods start following some event
  - time between events may be inconsistent

- Focus is on pure periodic data
PERIODIC DATA

- Initial Approach: Calendars (tabular layouts)

PERIODIC DATA

- Calendar (tabular) layouts exaggerate distance between adjacent periods
PERIODIC DATA

- Calendar (tabular) layouts exaggerate distance between adjacent periods
- Solution: layout the series in a spiral

Figure 1. A Spiral of Archimedes. (for color figures see the electronic proceedings or www.cs.umn.edu/~carlis)
PERIODIC DATA

- The end of one period is close to the start of the next.
- Encodes time with two visual attributes
  - distance from center is time
  - angle is time relative to start of period
- Values at time points must be encoded some other way
  - same with tabular layouts
PERIODIC DATA

- dot size
- line width

Figure 2. An indented spiral, with spokes, showing monthly consumption percentages for Baphia Cappanidifolia during the period 1980 – 1988.
PERIODIC DATA

- glyph

Figure 4. A spiral display of year-month consumption percentages for 12 highly consumed foods during the period 1980 – 1988. Rotated and zoomed in to show one season and boundary lines.
PERIODIC DATA

- Interaction
  - manually adjust period length

Figure 7. Tightening a spiral view of sound data from five instruments. From left to right the structure of the sound reveals itself.
PERIODIC DATA

- Interaction
  - change point of view (for 3D spirals)
PERIODIC DATA

- **good:**
  - space efficient
  - neighbouring points are always near each other
  - easy to tell where a point is within a period

- **bad:**
  - points within the same period may be very far apart
  - inconsistent density
  - can’t display many variables
    - glyph occlusion
    - bewildering 3D views
**Paper 2 & 3**

- **Visualizing and Discovering Non-Trivial Patterns in Large Time Series Databases**
  - Jessica Lin, Eamonn Keogh, Stefano Lonardi

- **Time-series Bitmaps: A Practical Visualization Tool for working with Large Time Series**
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Pattern Detection

- Observation:
  - sequence matching and pattern detection is a lot easier for strings

- Symbolic Aggregate approXimation (SAX)
  - dimensionality reduction
PATTERN DETECTION - SAX

- From initial time series...
First step, discretize time into \( w \) equal sized intervals

- aggregate the points within each interval (i.e., average)
Second step, discretize the value for each interval into an alphabet of size $\alpha$

- should result in equiprobable symbols
Linear trends could make patterns meaningless
- Could get patterns like aaaaabbbbbbbcccccc.

Use a short sliding time window
- symbols are equiprobable within the time window
- produces a set of strings instead of just one
**Pattern Detection – VizTree**

- **VizTree Idea:**
  - The set of strings produced by SAX can be encoded as a suffix tree
  - Using a time window of length 2, `cbabbbbaaacc` becomes `{cb, ba, bb, bb, ba, aa, ac, cc}`
PATTERN DETECTION — VizTREE

- Increase edge width paths containing large # of matching sequences
  - Frequent patterns and anomalies are easily recognizable
Instead of using node-link diagrams to represent a suffix tree, we can create a treemap:

- Encode # of matches as colour of each cell
- Restrict # of cells to a small value (~16)
PATTERM DTECTION – TIME SERIES BITMAPS

- Very difficult to interpret what a sequence looks like from the map
  - No good for analyzing an individual time series
- Easy/quick to compare different time series, useful for
  - overviews of many time series
  - spotting clusters & anomalies
PATTERN DETECTION

Good:
- Fast method for approximating time series as symbolic strings
- Easy to see common/uncommon subsequences with suffix trees
- Easy to compare multiple time series with bitmaps

Bad:
- unclear how to determine key parameters; (1) length of sliding window, (2) # of intervals to use, (3) alphabet size