WHAT IS TIME SERIES DATA?
- A value over time
- not too useful
- A sequence of time point + value pairs
  - <t0, v0>
  - <t1, v1>
  - <t2, v2>
  - ...
  - <tn, vn>

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)

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, Nishaanu Lolla, Eamonn Keogh, Stefano Lonardi, Chotirat Ann Ratananumhatana

TIME SERIES DATA
- Initial Approach: Calendars (tabular layouts)
- Calendar (tabular) layouts exaggerate distance between adjacent periods
- Solution: layout the series in a spiral

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
- 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
- The end of one period is close to the start of the next.
  - 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

**PERIODIC DATA**
- glyph

**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
  - Nitin Kumar, Nishanth Lolla, Eamonn Keogh, Stefano Lonardi, Chotirat Ann Ratanamahatana

**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

**Pattern Detection**
- Observation:
  - Sequence matching and pattern detection is a lot easier for strings
- Symbolic Aggregate approximation (SAX)
  - Dimensionality reduction

**Pattern Detection - SAX**
- Linear trends could make patterns meaningless
  - Could get patterns like aaaaabbbbbbccccc.
- 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 cbabbbaaacc becomes {cb, ba, bb, bb, ba, aa, ac, cc}

**Pattern Detection - Time Series Bitmaps**
- 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)