

Multi-Level Visualization for the Exploration of Temporal Trends in Simulation Data

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Motivation

Huge volumes of temporal data at multiple scales generated by 4 different Modeling & Simulation process levels (Model, Experiment, Multi Run, Single Run) need to be visually analyzed

→ Approaches of visual analysis based on global trends in the data is insufficient

Starting point

Multiple views visualization framework MOSAN[1], combining all 4 levels of the process hierarchy: model + time series visualization

Trend similarity measure[2] defines the piecewise similarity of two time series based on their trends.

$$trend(slope) = \begin{cases} 1 & slope > 0 \text{ increasing} \\ 0 & slope = 0 \text{ constant} \\ -1 & slope < 0 \text{ decreasing} \end{cases} \quad td(slope_1, slope_2) = \begin{cases} 0 & \text{if } (trend(slope_1) = trend(slope_2)) \\ 1 & \text{if } (trend(slope_1) \neq trend(slope_2)) \end{cases}$$

$$trendSim = \frac{1}{segNum} \sum_{i=1}^{segNum} td(trend(slope_1), trend(slope_2))$$

Visual Analytics Approach

Main Idea: multiple views + hierarchical clustering + trend based similarity measure

1. Hierarchical clustering by global trends over multiple runs of a single element and clustering over all elements of a single run
2. Representation of global trends in all process levels
3. Representation of local trends at multiple levels of details by means of interaction

Color scales + manual selected local time frame used in all views

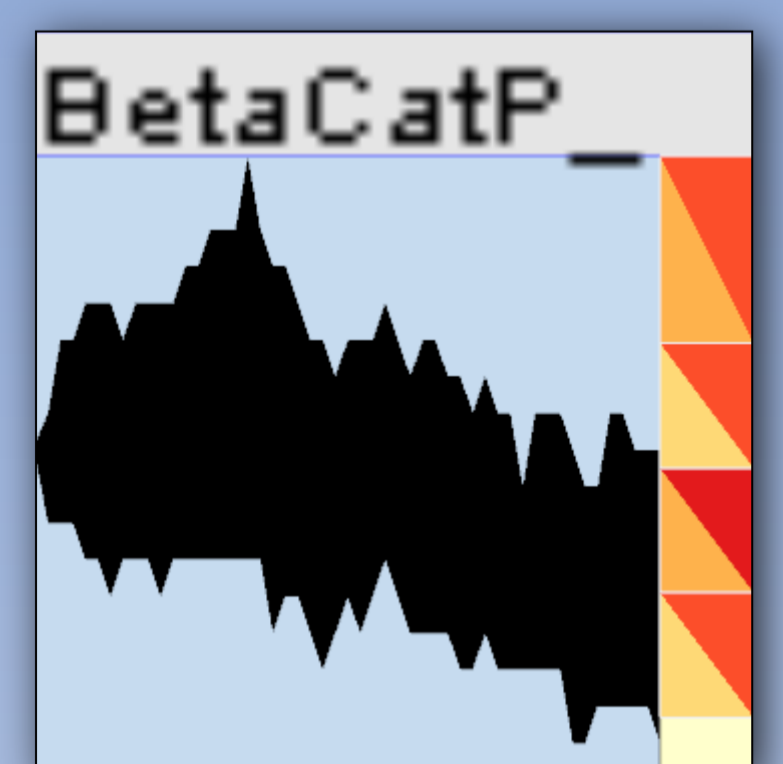


1. blue: Color scale to handle data values scales
2. green: Cluster quality to communicate homogeneity of clusters
3. red: Cluster quality to communicate inhomogeneity of cluster
4. dark grey: local time frame for comparing local and global cluster quality

Multi-Level, Multiple View Visualization Framework

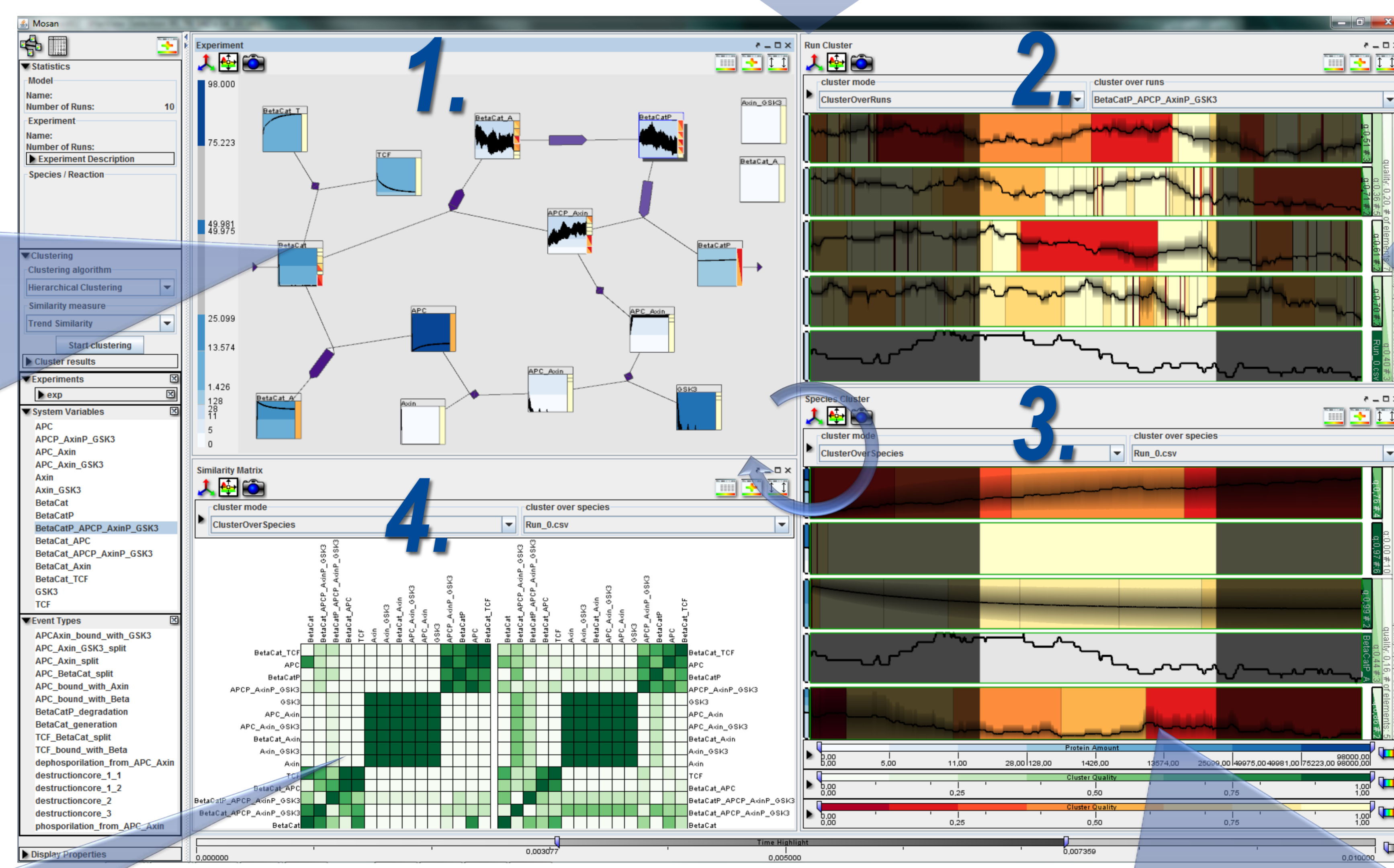
Multiple views showing the different process levels at multiple levels of granularity: 1. Combined Model and Experiment View showing all elements and their interplay, 2. Multi Run View showing clustered time series of one element for all runs, 3. Single Run View showing clustered time series of all elements for one run, 4. Similarity Matrix View showing clusters in a global and local time frame.

First Granularity Level: Element icons of model view showing main clusters

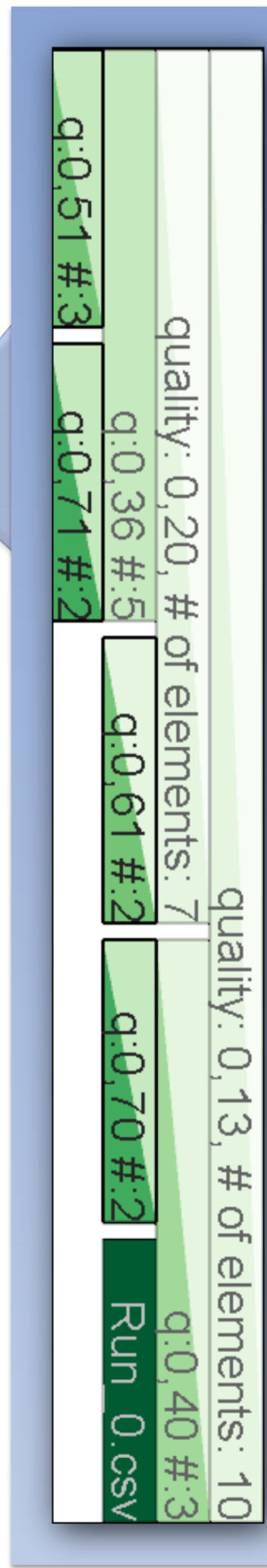


Foreground: aggregated time series over all runs
Right: main clusters + global quality (lower left triangles) + local quality (upper right triangles)

Example of a heterogeneous cluster. Red color highlights low quality of clusters, starting points for further investigation.



Second Granularity Level: Cluster hierarchy view showing trend quality



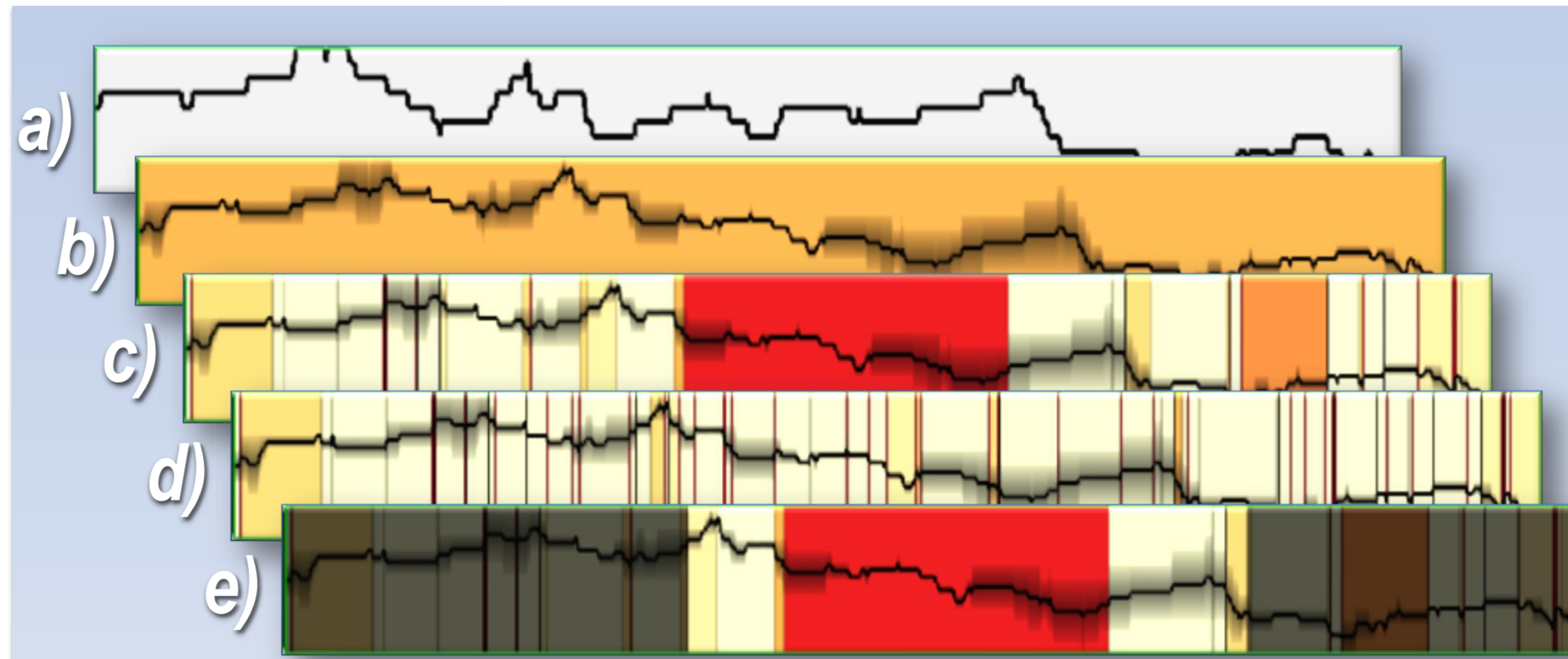
Rectangles: icons for representing all clusters + global quality (lower left triangles) + local quality (upper right triangles)

The cluster hierarchy is automatically expanded to show high quality clusters from the beginning.

Fourth Granularity Level: Similarity matrix visualization showing quality per element

Left: global similarity matrix. Right: local similarity matrix.

Clusters are visible by groups of green matrix cells. The quality of a cluster may change for a selected time frame. By comparing the global and local matrix the difference of local and global quality can be estimated and new clusters can be found.



Third Granularity Level: Time series chart showing trend and local quality for a single cluster

Foreground: aggregated time series chart showing min/max and average values. Background: local cluster quality with interactive level of detail.

a) single time series distinguishable by grey background. b-d) low, mid and high detailed local cluster quality to identify heterogeneous local trends. e) selected temporal frame

[1] Unger, Andrea and Schumann, Heidrun.: Visual Support for Understanding of Simulation Processes, in proc. of IEEE Pacific Visualization Symposium, 2009

[2] Li, Guiling and Wang, Yuanzhen and Zhang, Lipping and Zhu, Xiaolian.: Similarity measure for time series based on piecewise linear approximation, in proc. of Wireless Communications Signaling Processing, 2009