CloudDet: Interactive Visual Analysis of Anomalous Performances in Cloud Computing Systems

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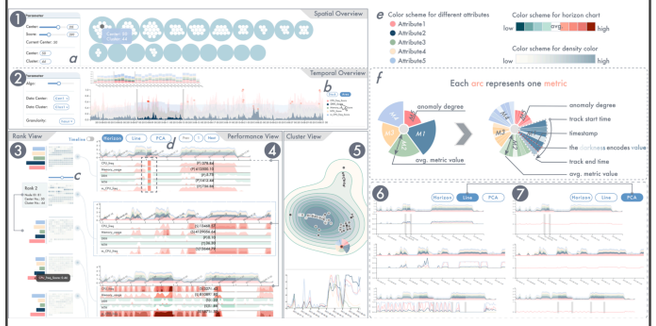
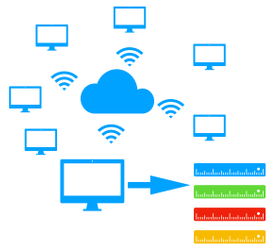
CloudDet



Motivation

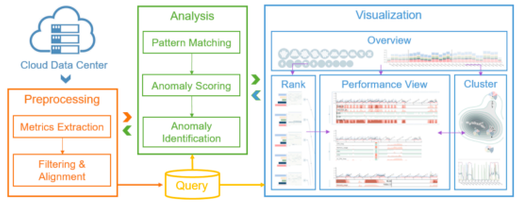
- Monitoring nodes instead of monitoring applications
- Too many **false positives**, **scale** problem.
- Visualization of anomalies: **Intuitiveness**, **interaction**.
- **Research Contribution: Detection system, Visualization, Evaluation**



Visualization Challenges

- **Scale**: Trade-off between system scalability and level-of-detail(LoD)
- **Multi-dimensionality**: Temporal patterns, Relation between metrics
- Boundary **normal/abnormal**

System Overview



What is abnormal and what is not? How to detect?

Mathematics!

$$P(f_{k/N}) = ||X(f_{k/N})||^2,\ k = 0, 1...[\frac{N-1}{2}], \quad (1)$$

$$ACF(\tau) = \frac{1}{N}\sum_{n=0}^{N-1} d(\tau)\cdot d(n+\tau),\ \tau = 0, 1...[\frac{N-1}{2}]. \quad (2)$$

$$d_n = S_n + Tr_n + R_n,\ n = 1, 2...N, \quad (3)$$

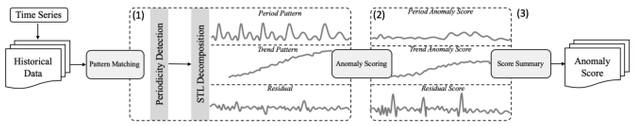
$$AS_{periodic} = min\left(\left|\frac{T_n - T_{n-1}}{T_{n-1}}\right|, 1\right), \quad (4)$$

$$AS_{trend} = min\left(\left|\frac{K_n - K_{n-1}}{K_{n-1}}\right|, 1\right), \quad (5)$$

$$AS_{spike} = min\left(\left|\frac{R_n - \mu_{n-1} - 3\sigma_{n-1}}{3\sigma_{n-1}}\right|, 1\right), \quad (6)$$

$$AS = f(AS_{periodic}, AS_{trend}, AS_{spike}), \quad (7)$$

Algorithm Flow



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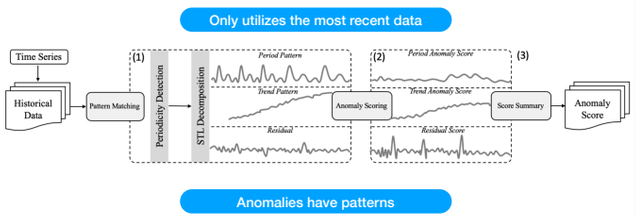


Design Tasks

- **T1** Overview of anomalies for data query
- **T2** Ranking suspicious nodes dynamically
- **T3** Browse data flexibly
- **T4** Facilitate anomaly detection
- **T5** Similarities of nodes

Visualization

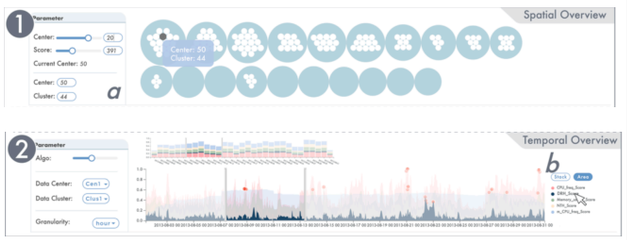
Encoding Protocol

Global Categorical Colors: performance metrics (CPU Frequency, Memory Usage,…)

Linear Color Scheme: Anomaly score

Diverging Color Scheme: Difference of performance metrics to average

Spatial and Temporal Views



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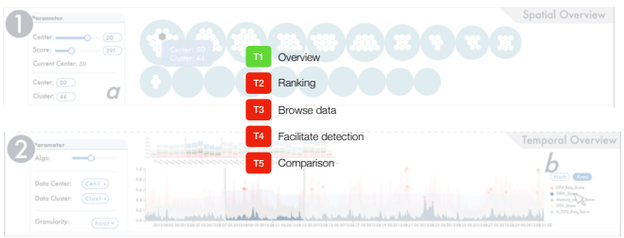
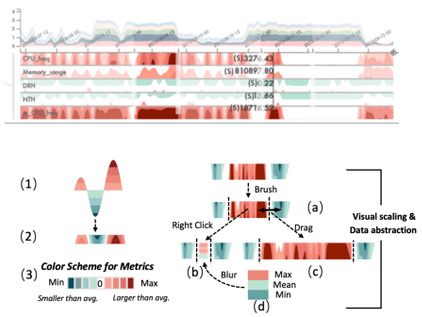


Rank and Performance View

Horizon Chart

Interactions:

- Brushing
- Collapsing
- Stretching



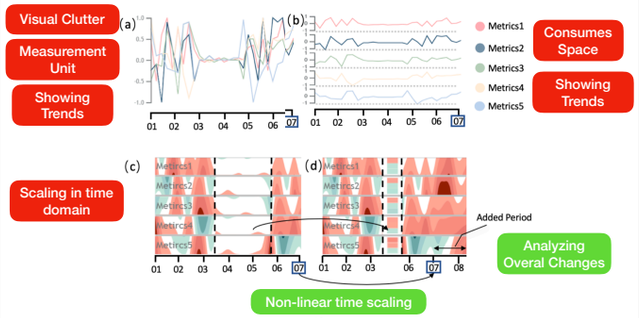
Line mode

- Each line for one metric
- More conventional
- Normalize data to [-1,1]

PCA mode

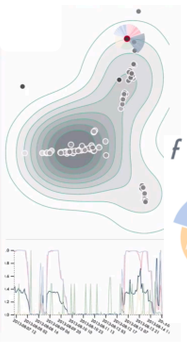
- Project a multivariate data to a one-dimensional time-series data
- Major Trend

Alternative Designs

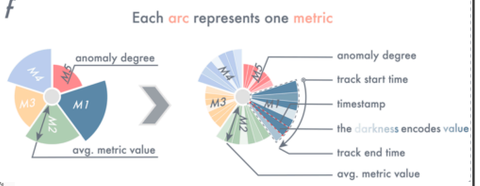


Rank and Performance View

The Cluster View

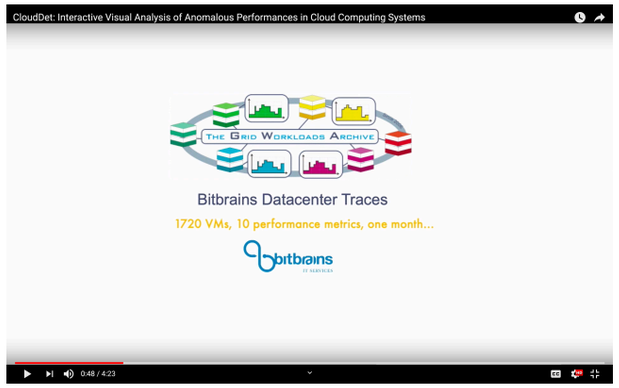


- Dimensionality reduction.
- Another perspective for anomaly diagnosis
  - White contour: most probably anomaly
  - Gray contour:normal.



The Cluster View

Official Video (1:05 min)



What-Why-How Summary

What	Why	How
Multi-variate time-series quantitative performance data from compute nodes.	•Anomaly Ranking •Anomaly inspection •Anomaly Clustering	•Colors and brightness •horizontal and line chart •Special glyphs •Spatial positions of nodes and charts. •Interactivity: Scrolling, Brushing, and setting parameters

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Scalability

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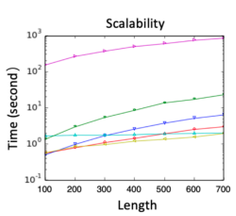
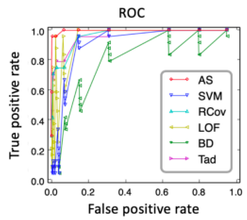
Scale — Very Scalable: scale **linearly** with time-series input data size

Evaluation

Quantitative Evaluation





Case Studies

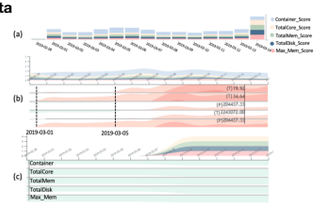
Case Study 1: Bitbrains Datacenter Traces

500 VMs, One month

Case Study 2: Live Cloud System Data

1,000,000 nodes, Two weeks

[100 data centers with 20 data clusters with 500 nodes each]



User Feedback

- Automated Anomaly Detection: **Trust** in algorithm,
- System: **Useful** and **User-friendly**, **Consistent**, too **comprehensive** and **Overwhelming, Need Tutorial**
- Visualization and Interaction: **Helpful**, **new perspective** for overall trend, **clear comparison**, Confess that they use chaotic line charts before.

Critique

Positive

- Alternative designs
- Super-scalable
- Perfect evaluation
- Very Accurate
- Special Glyphs

Negative

- Better to use non-diverging colors for horizon charts.
- Minor occlusion in the clustering.
- Make use of global colors in horizontal chart.
- Bad way for Assigning the ranks to performance.
- Empty clusters in spatial overview.
- Limitation: Just consider recent data and one metric.
- Limitation: Don’t discuss why using those performance metrics for anomaly.

Question?