Study Notes for Comp 4350: Software Engineering II - Lecture 7

AIOps (Artificial Intelligence for IT Operations)

- **Definition**: AIOps combines big data, machine learning, and visualization to enhance IT operations like deployment and monitoring. It addresses DevOps challenges with AI.

Monitoring in DevOps

- Critical for quality assurance in IT services.
- Involves logs, metrics, and traces.
- Increasing data volume and complexity require efficient monitoring tools.

Artificial Intelligence (AI)

- **Definition**: Simulation of human intelligence processes by machines, including learning, reasoning, and self-correction.
- Two approaches: Knowledge-based (e.g., autopilot systems) and machine learning-based (e.g., AlphaGo).

Machine Learning Techniques

- Common techniques include:
  - Semi-supervised learning
  - Classification (categorical)
  - Regression (numeric)
  - Frequent pattern mining

Frequent Pattern Mining

- Finding sets of items that frequently occur together.

Clustering

- Grouping a set of objects into classes of similar objects.

Anomaly Detection

- Identifying data points, events, or observations that deviate from a dataset's normal behavior.

Autonomous Configuration of Software Systems

- Manually configuring large-scale systems is costly and error-prone.
- Autonomous configuration aims for self-monitoring, self-configuring, and self-optimizing systems.

Performance and Workload

- Performance is influenced by a system's configuration and the characteristics of its workload.

Autonomous Configuration and Its Challenges

- Ensuring minimal footprint, fast response, and understanding the relationship between configuration parameters and performance.
- Avoid exhaustive testing due to feasibility.

Mining Monitoring Data

- Utilizing logging data right involves parsing, abstracting, and analyzing for diagnostics, anomaly detection, and incident prediction.

Methodology for Performance Debugging

- Process includes extracting of interest, mining frequent patterns, and clustering for analysis.

AIOps Research Sub-Areas

- Automated logging, log abstraction, anomaly detection, performance analysis, incident prediction, logging practices, fault diagnostics, system comprehension, autonomous configuration, AIOps infrastructure, generating monitoring code right, using monitoring data right.

Log Parsing

- First step in log analysis tasks.
- It is the process of converting unstructured log data into a structured data format.

Case Studies

- Examples include detecting performance bugs in Windows Explorer UI and predicting node failures in cloud platforms.

Predictive Analytics in AIOps

- Predicting failures in cloud systems using monitoring data to recognize differing patterns between failed and normal nodes.

Scenario Exercise

- For predicting runtime failures in the next two hours, use Anomaly detection or Incident prediction solutions.

References

- Includes studies and reports from EMSE, ICSE, JSME, ICSM, TOSEM, and other reputable sources on various topics related to AIOps.

Observer Effect

- Observation of a system can itself perturb the system, known as the observer effect.

Class Notes

Slide 1

Title: Comp 4350 Software Engineering II Lecture 7
Dr. Shaowei Wang

Slide 2

Title: Agenda

- What is AIOps
- Motivating example
- Sub-areas of AIOps research

Slide 3

Title: AIOps (Artificial Intelligence for IT Operations)

- AIOps enhances IT operations (deployment and monitor) through greater insights by combining big data, machine learning, and visualization.
- Addresses DevOps challenges with AI
- From: 2018 Gartner

Slide 4

Title: Monitoring is critical for ensuring the quality of the delivered services

- deploy
- operate
- test
- build
- code
- plan
- release
- Dev
- Ops
- monitor

Slide 5

Title: Monitoring is critical for ensuring the quality of the delivered services

- deploy
- operate

- test
- build
- code
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- Dev
- Ops
- monitor
- Logs
- Metrics
- Traces

Slide 6

Title: Increasing volume and complexity of monitoring data

- Production Environments
- Billions of logs, metrics, and alerts per day
- Human Brain
- Hundreds/thousands of events
- Analysis of big and complex monitoring data poses challenges to software monitoring.

Slide 7

Title: What is AI?

- Simulation of human intelligence processes by machines, especially computer systems.
- Includes learning, reasoning, and self-correction.

Slide 8

Title: Common machine learning techniques

- Semi-supervised
- A small amount of labeled data with a large amount of unlabeled data.

Slide 9

Title: Classification (categorical)

Slide 10

Title: Regression (numeric)

Slide 11

Title: Frequent pattern (itemset) mining

- Goal: finding sets of items frequently occurring together

Slide 12

Title: Definition: Frequent Itemsets Body:

- Itemset: a set of items
- E.g., acm={a, c, m}
- (absolute) Support of itemsets
- Sup(acm)=3
- Given min_sup = 3, acm is a frequent pattern
- Frequent pattern mining: find all frequent patterns in a database
- Transaction database

Slide 13

Title: Clustering: the process of grouping a set of objects into classes of similar objects

Slide 14

Title: Anomaly detection

- Identifies data points, events, or observations that deviate from a dataset's normal behavior.

Slide 15

Title: Beyond Ops: Making monitoring code right

- Monitoring code made right
- Monitoring data used right
- Monitoring code
- Monitoring data

Slide 16

Title: Motivating Example Body: Autonomous configuration of large-scale software systems

Slide 17

Title: Manually configuring large-scale software systems is costly & error-prone

- Software system
- Workload
- Performance
- Configuration
- Unsatisfied perf.?
- Workloads are constantly evolving, requiring constant human intervention for optimal performance

Slide 18

Title: Parameters of Database system Body:

- Cache.size
- Fetch.blocksize
- Table.pageReserve

- ...

Slide 19

Title: Characteristics of Workload Body:

- Number of user requests
- Query type (insert, fetch)
- Size of each fetch
- Frequency of queries on each table
- ...

Slide 20

Title: Optimization goal Body:

- Minimize the latency of queries on average
- Use minimal memory

Slide 21

Title: Using an AIOps solution to autonomously tune system configurations

- Software system
- Self-monitoring
- Self-configuring
- Self-optimizing
- Optimized parameter values
- Logs
- Performance measures
- Metrics
- [Li et al. 2018]

Slide 22

Title: Challenges in autonomous configuration of large-scale software systems

- Complex system behavior
- Minimal footprint
- Fast response to environment
- [Li et al. 2018]

Slide 23-24

Title: Challenges in autonomous configuration of large-scale software systems

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Slide 25

Title: Understanding the relationship between config. parameters and performance metrics

- Asking domain experts
- Perf. related parameters
- Perf. data
- Impact of parameters?
- Running tests
- [Li et al. 2018]

Slide 26

Title: Blue force approach Body:

- Exhaustively run different combinations of parameter values.
- Too many combinations become infeasible.
- Multivariate Adaptive Regression Splines (MARS)
- [Li et al. 2018]

Slide 27

Title: Understanding the relationship between config. parameters and performance metrics

- Perf. related parameters
- Perf. data
- Perf. critical parameters
- Running tests
- Only a few candidate parameters significantly impact system performance.
- Multivariate Adaptive Regression Splines (MARS)
- [Li et al. 2018]

Slide 28-29

Title: Challenges in autonomous configuration of large-scale software systems

- Complex system behavior
- Minimal footprint
- Fast response to environment
- [Li et al. 2018]

Slide 30

Title: How to capture KPI for different settings of parameters Body:

- Simulating the behavior of different parameter settings and recording them.
- Slow but accurate
- Historical data: pairs <parameters, KPIs>
- Fast but less accurate

Slide 31

Title: Machine learning-based Body:

- Use accumulating data to train ML models for auto-tuning parameters.
- Pairs <characteristics of current workload, settings of parameter>

Slide 32-33

Title: Challenges in autonomous configuration of large-scale software systems

- Complex system behavior
- Minimal footprint
- Fast response to environment
- [Li et al. 2018]

Slide 34

Title: Separating the autonomous configuration capabilities from the original system

- Software system
- Self-monitoring
- Self-configuring
- Self-optimizing
- Optimized parameter values
- Remote control
- Logs
- Performance measures
- Metrics
- [Li et al. 2018]

Slide 35-36

Title: Autonomous configuration significantly improves system performance

- Low workload, KPI is optimal
- High workload, KPI drops
- Autonomous configuration
- [Li et al. 2018]

Slide 37-40

Title: Sub-areas of AIOps research

- Automated logging
- Log abstraction
- Anomaly detection
- Performance analysis
- Incident prediction
- Logging practices
- Fault diagnostics
- System comprehension

- Autonomous configuration
- AIOps infrastructures
- Generating Monitoring code right
- Using Monitoring data right

Slide 41

Title: Log parsing is the first step for many log analysis tasks

- Fault diagnostics
- Anomaly detection
- System comprehension
- Parsing splits unstructured log data into structured format.

Slide 42-43

Title: Log parsing is the first step for many log analysis tasks

- Fault diagnostics
- Anomaly detection
- System comprehension

Slide 44

Title: Why we need this? Reduce the size

- [Jiang et al. 08]

Slide 45

Title: How many types of “errors” are there? – prioritize work based on frequency Body:

- Enterprise application generates 1.6 million log lines in 8 hours; 23,000 lines contain “fail” or “failure”
- Total 319 execution events; 16 contain “fail” or “failure”
- [Jiang et al. 08]

Slide 46

Title: Sub-topics of AIOps research

- Automated logging
- Log abstraction
- Anomaly detection
- Performance analysis
- Incident prediction
- Logging practices
- Fault diagnostics
- System comprehension
- Autonomous configuration
- AIOps infrastructures
- Generating Monitoring code right

- Using Monitoring data right

Slide 47

Title: Fault diagnostics

- Identify the root leading to the fault and its location

Slide 48-49

Title: Performance Debugging in the Large via Mining Millions of Stack Traces - Microsoft

- Performance bugs slow down the system
- Windows collects millions of execution traces
- Call stack analysis for system slowdown
- [ResearchGate Link]

Slide 50-51

Title: Using clustering to reduce the size

- Group related execution trace patterns for large-scale performance debugging
- Select representative patterns from each cluster

Slide 52-53

Title: Methodology

- Extract area of interest
- Extract frequent sequential patterns
- Cluster patterns based on similarity measure
- Hierarchical clustering
- [Alignment of patterns]

Slide 54

Define cost of alignment (edit cost) and get optimal alignment.

Slide 55

Title: Experiment

- Finding hidden performance bugs on Windows Explorer UI
- Input: 921 trace streams, 140 million call stacks
- Output: 1,215 pattern clusters
- Detection of 12 highly impactful performance bugs
- [Li et al. 2018]

Slide 56-60

Title: Sub-topics of AIOps research

- Automated logging
- Log abstraction
- Anomaly detection
- Performance analysis
- Incident prediction
- Logging practices
- Fault diagnostics
- System comprehension
- Autonomous configuration
- AIOps infrastructures
- Generating Monitoring code right
- Using Monitoring data right
- Case study on Dell DVD Store
- 99.99% reduction in viewed log lines with a precision of 56-100%

Slide 61-64

Title: Predicting Node Failures in an Ultra-large-scale Cloud Computing Platform

- Early monitoring data shows differences between failed nodes and normal nodes.
- [Li et al. 19]
- AUC: 0.92

Slide 65-66

Title: Exercise: select the AIOps solutions for given scenarios

- Given existing monitoring data, determine runtime failure in the next two hours.
- A. Fault diagnostics
- B. Anomaly detection
- C. Incident prediction

Slide 67-69

Title: References

- Various papers on AIOps topics

Slide 70-73

Title: Comparing system performance with a baseline derived from previous runs

- Distribution, Evolution, Step-wise Performance Diagnosis
- [Jiang et al. 09]

Slide 74

Title: When you observe a system, you are perturbing it. No free lunch

- Observer effect applies to monitoring software systems