



## SEARCH FOR ANOMALIES IN THE COMPUTING JOBS EXECUTION OF THE ATLAS EXPERIMENT WITH THE USE OF VISUAL ANALYTICS

**M. Grigorieva<sup>1</sup>, T. Galkin<sup>2</sup>, T. Korchuganova<sup>3</sup>, I. Milman<sup>2</sup>, V.  
Piluygin<sup>2</sup>, M. Titov<sup>1</sup>**

<sup>1</sup>NRC "Kurchatov Institute"

<sup>2</sup>NRNU "MEPHI"

<sup>3</sup>NR TPU

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# Outline

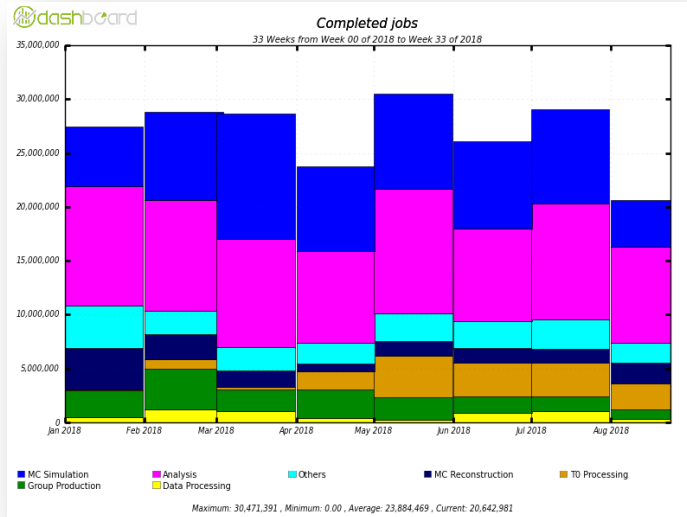
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- Computing challenges in the ATLAS experiment
- Problem statement
- ATLAS data sources
- Proposed approach of visual analytics
- Analysis of ATLAS jobs execution
- Interpretation of the results
- Conclusions and future work

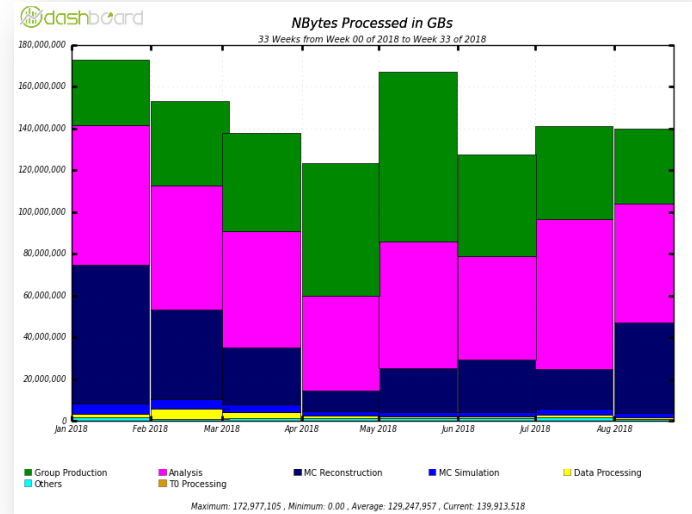
# Computing Challenges in ATLAS

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From ATLAS Dashboard <http://dashb-atlas-job.cern.ch/>



Statistics for time period: 2017-01-01 – 2018-08-01



## ATLAS STATS

### Computing Resources:

- WLCG
- Opportunistic resources
  - HPC, Academic clouds, University clusters, Volunteer computers
- Total for more than decade:
  - 10 millions of tasks
  - 3 billions of jobs

- **TASK** is an activity that needs to be accomplished within a defined period of time. It contains execution code and input/output files, corresponding to underlying physics process and initial conditions.
- Each task is fragmented in **JOBS** which correspond to a fixed number of events.

# Problem Statement

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- **Large-scale distributed system in ATLAS faces the following challenges:**
  - Big diversity and complexity
  - Highly dynamic computing environments
  - Ongoing competition between different threads of computing jobs
  - Complex workflow of jobs execution
  - Uncountable possible reasons of failures and unstable behavior
- **A fundamental goal is to increase the stability and efficiency of the distributed data processing and analysis systems.**
  - **Current task:** The analysis of jobs execution process
- **What should be done?**
  - Development of analysis algorithms and tools using ML and statistics methods for detection of disruption of the operational process of workload management systems in ATLAS
  - Development of interactive methods and tools of visual analytics, providing the use of dynamic and static spatial interpretations of the analyzed data.

# Visual analytics of multidimensional data

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Visual Analytics combines data visualization with ML and other automated techniques to create systems that help people make sense of data.

**Typically, domain experts have limited involvement in the process of data analysis.**

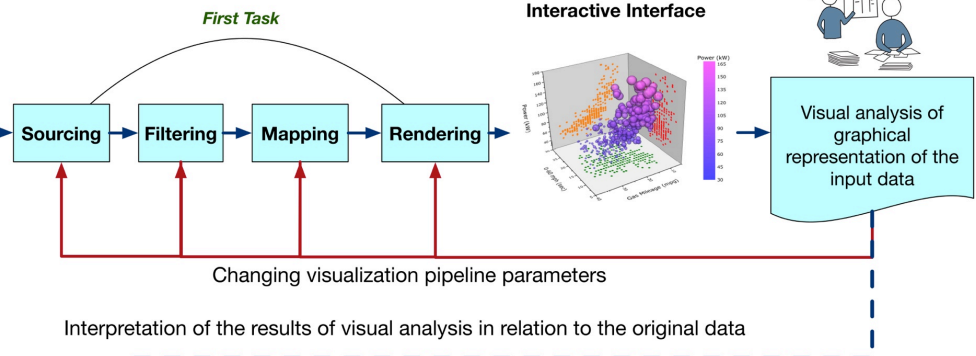
Traditional machine-learning workflow: practitioners collect data, select features, preprocess and transform the data, choose a representation and learning algorithm to construct the model, tune parameters of the algorithm, and finally assess the quality of the resulting model.

This assessment often leads to further iterations on many of the previous steps.

**Domain experts** involvement in this process is mediated by the practitioners and is limited to providing data, answering domain-related questions, or giving feedback about the learned model. This results in a design process with lengthy and asynchronous iterations and limits the end users' ability to affect the resulting models [1].

By integrating ML algorithms with interactive visualization, visual analytics aims at providing visual platforms for analysts to interact directly with data and models.

SE	Shards/bytes	#Nodes	#Racks	Size	Ref	#Rack
1	4.5T	75,001,462	2,563,827	50.2B	None	1
2	4.2T	71,000,100	1,866,017	46.0B	None	1
3	4.6T	107,760,394	4,702,639	120.2B	None	1
4	4.2T	62,000,019	1,121,077	79.0B	None	1
5	11.6T	4,481,027	126,831	77.4GB	None	1
6	7.2T	76,268,887	2,643,917	79.0B	None	1
7	0.8T	7,820,139	114,279	1.6GB	None	1
8	1.5T	19,262,794	294,211	1.5GB	None	1
9	3.8T	111,441,021	2,703,681	94.0B	None	1
10	4.7T	46,000,761	1,306,761	1.5GB	None	1
11	0.5T	4,500,282	107,261	1.5GB	None	1
12	1.2T	11,025,264	152,471	1.5GB	None	1
13	16.3T	30,888,326	1,023,381	94.0B	None	1



[1] D. Sacha. What you see is what you can change: Human-centered machine learning by interactive visualization // Neurocomputing 268 (2017) 164-175

# ATLAS Data Sources and Job Execution Metrics

6

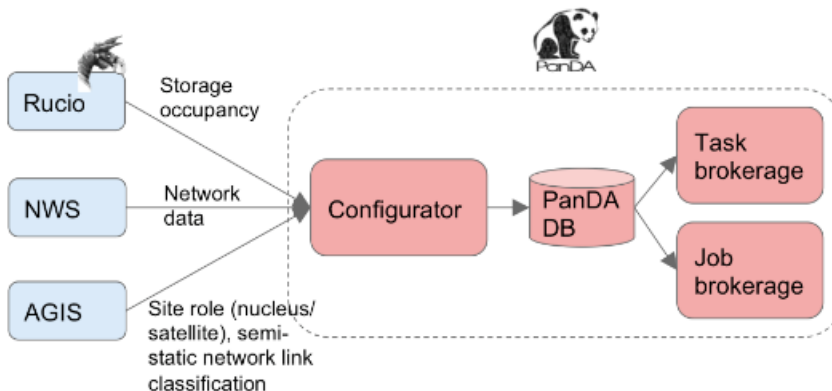
## ATLAS Data Sources

- Rucio (Distributed Data Management System)
- NWS (Network Weather Service)
- AGIS (ATLAS Grid Information system)
- DEFT (Database Engine for Tasks)
- JEDI (Job Execution and Definition Interface)
- PanDA MemoryMonitor

ATLAS-Kibana  
(ElasticSearch)

## Job Execution Metrics

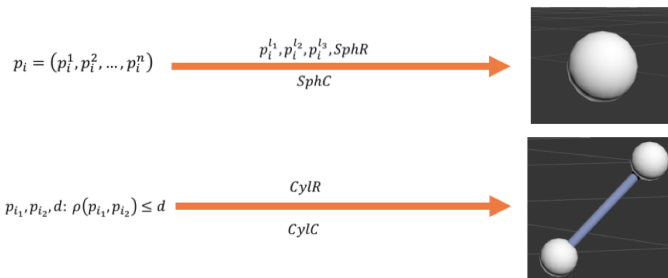
- Application-level
  - Job description, status, input/output files, start/end time
- Middleware-level
  - Data transfer service, scheduler(queues), computing element, storage management
- Network-level
  - Network connection status, data transfer rate between sites
- Resource-level
  - CPU utilization, memory/storage usage, packet I/O rates



# The proposed method of multidimensional data visual representation

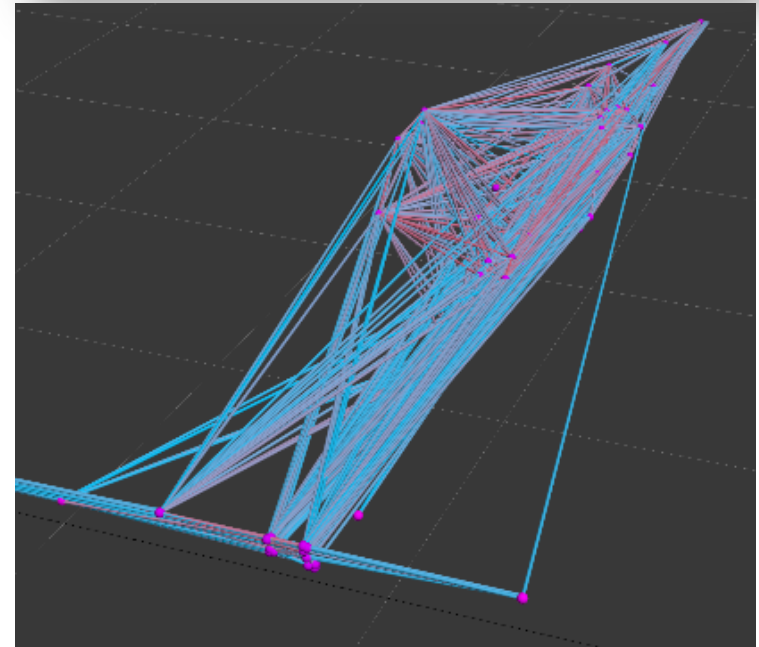
7

- Jobs = multidimensional points, parameters values = coordinates
- Euclidean or Mahalanobis distances is calculated between all pairs of points
- Points are projected to a 3-dimensional space and drawn as spheres
- If distance between points is less than the threshold, then a cylinder is constructed to connect the spheres
  - ▣ Threshold can be changed interactively, allowing to observe the changes in the cluster structure
- The color of the cylinder simulates the distance between the points from red (small distance) to blue (close to the threshold):



## Representation of computing jobs execution (multidimensional tabular data)

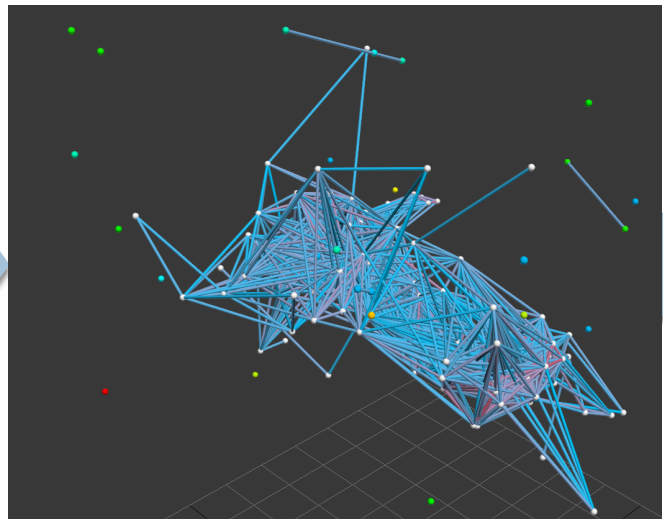
	Parameter 1	Parameter 2	...	Parameter n
Job 1	$x_{11}^j$	$x_{12}^j$	...	$x_{1n}^j$
...	...	...	...	...
Job i	$x_{i1}^j$	$x_{i2}^j$	...	$x_{in}^j$
...	...	...	...	...
Job m	$x_{m1}^j$	$x_{m2}^j$	...	$x_{mn}^j$



# Multidimensional visual analysis software prototype

- First prototype is created based on **Autodesk 3ds Max**
- A combination of **MAXScript** scripts and **C#** module was used
- Depending on the amount of RAM, the software can handle up to a couple of hundreds of objects
- Points (Spheres) are coded with colors
- Results can be exported to excel (xlsx) files

```
2 6.962112 24.5123 78.90181 21.98576 30.10471 23.73668 19.69169 61.57939 8.72603 8.01488 76.71998 96.58159
3 58.8037 82.2403 18.86897 4.10576 27.92312 1.046999 68.00812 0.970729 5.399256 10.4745 46.08335 61.5777
4 5.02502 99.48159 6.41196 6.48878 4.26518 68.00809 51.61282 4.808997 61.46179 59.6315 61.7131
5 97.27088 56.86417 41.44222 12.67982 62.1242 15.13939 59.79035 13.3096 12.04388 62.67603 62.26742 97.51109
6 0.520292 0 8.170378 1.90802 24.65445 1.14139 31.11348 35.26438 1.76501 17.89046 66.9061 60.50177
7 55.75916 95.23413 31.38121 1.378361 56.70699 7.58522 81.28813 10.09183 6.556338 44.99567 65.6048 97.40745
8 61.28267 95.43898 21.8887 1.904664 41.15108 1.888411 95.00312 0.89091 1.257708 42.33204 90.91155 91.01259
9 10.11090 99.74555 94.0663 15.88492 31.50785 0.017188 99.81181 10.72129 34.38645 89.68439 99.7719 99.62238
10 9.03805 99.87277 5.83828 15.72124 20.8421 8.31645 62.49335 6.88282 68.49913 45.47748 86.23811 97.95951
11 50.81032 78.74384 37.97517 8.403566 37.88627 1.244966 66.29236 12.56482 62.42995 94.00718 76.52671 88.10208
12 14.65258 90.80207 30.82327 7.70237 47.32084 14.51071 50.72143 8.017082 1.453752 46.47485 56.85622 63.33809
13 14.82149 24.81517 61.1484 35.80205 12.48073 10.1317 60.02454 19.20231 12.27149 80.2098 78.209 97.29861
14 72.80084 24.78372 25.95552 1.089249 34.45969 16.58889 14.11295 81.21106 1.540122 57.82248 84.80275 78.51383
15 10.65882 62.06531 1.83155 1.338842 11.12595 14.52676 65.62236 1.376645 1.708515 20.97963 43.59664 48.57309
16 40.7768 68.62663 63.82718 11.89885 40.1178 4.497748 60.01896 14.87791 61.32613 62.44403 80.56612 86.13081
17 40.12472 22.00547 35.88879 4.468443 49.21466 6.176235 14.63328 39.88857 6.476834 69.82465 72.8248 76.46542
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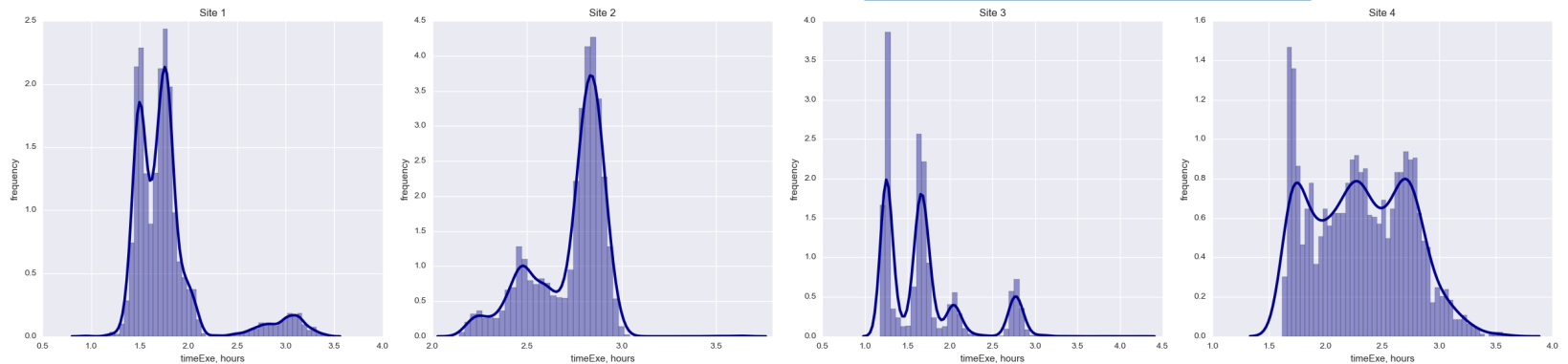
# General Case Hypothesis

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- Task №14138001 (may-june 2018) ~50 000 jobs, 108 computing sites

Distributions of jobs' execution time and CPU time on computing sites should match

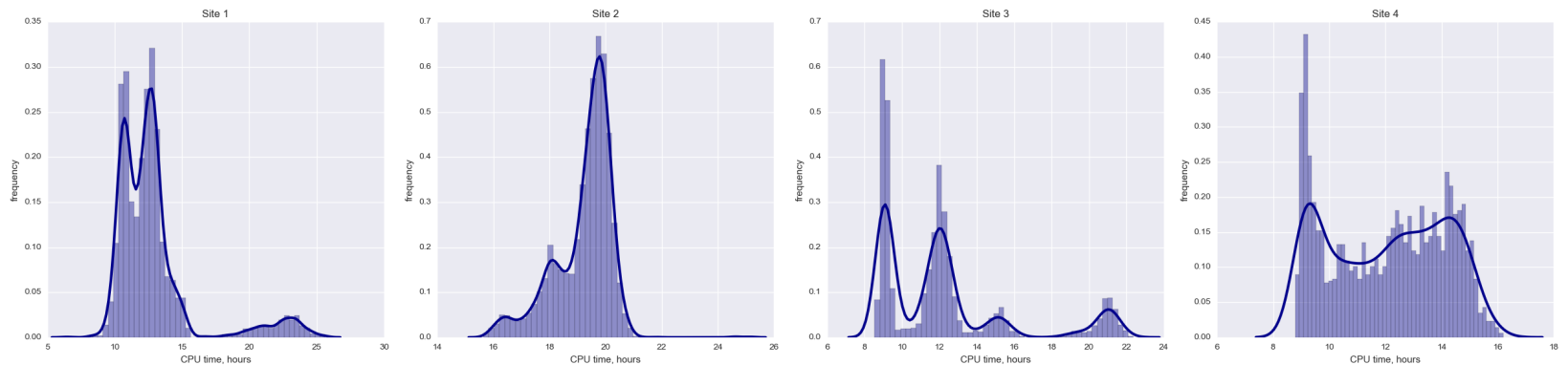
## TimeExe Distributions



Bars indicates the number of jobs, having the same execution time.

Lines – univariate distribution of observations.

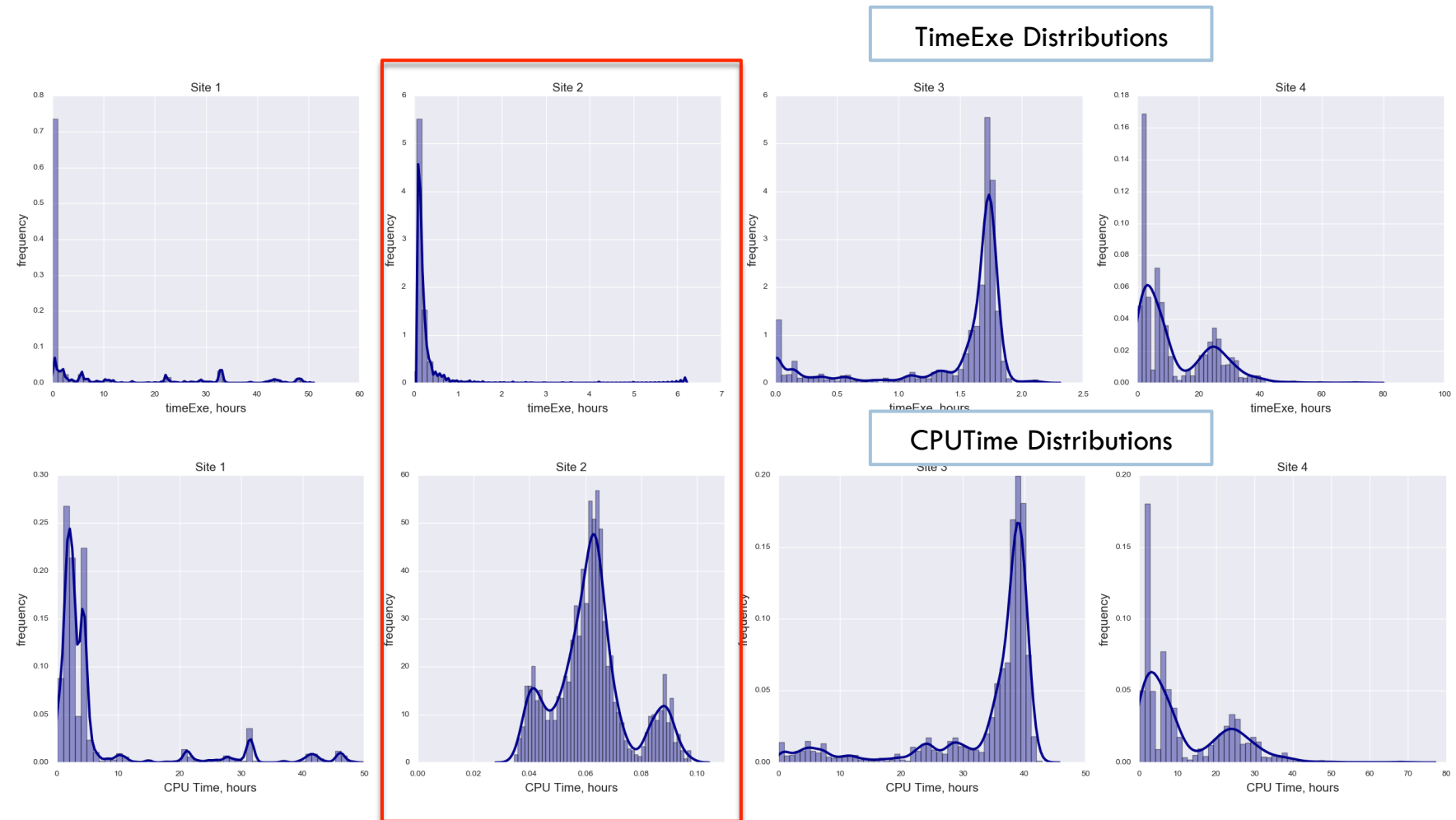
## CPUTime Distributions



# Non-trivial jobs execution on computing site

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- Task №14296407 (may-june 2018), number of jobs ~ 9000, 18 computing sites



# Site 2 analysis

Task №14296407

11

- **Remove unnecessary features**
  - Features with a high percentage of missing values
  - Collinear (highly correlated) features
  - Features with a single unique value
- Dependent feature – **WallTime**
- **RandomForestRegressor** - to retrieve features importances for the dependent feature
- **K-means clustering** - to split initial data sample into 200 data clusters
- Visual analytics prototype was applied to this data sample to build 3D spatial scene
- Distance threshold between spheres, calculated as **Mahalanobis distance**, was tuned using interactive interface

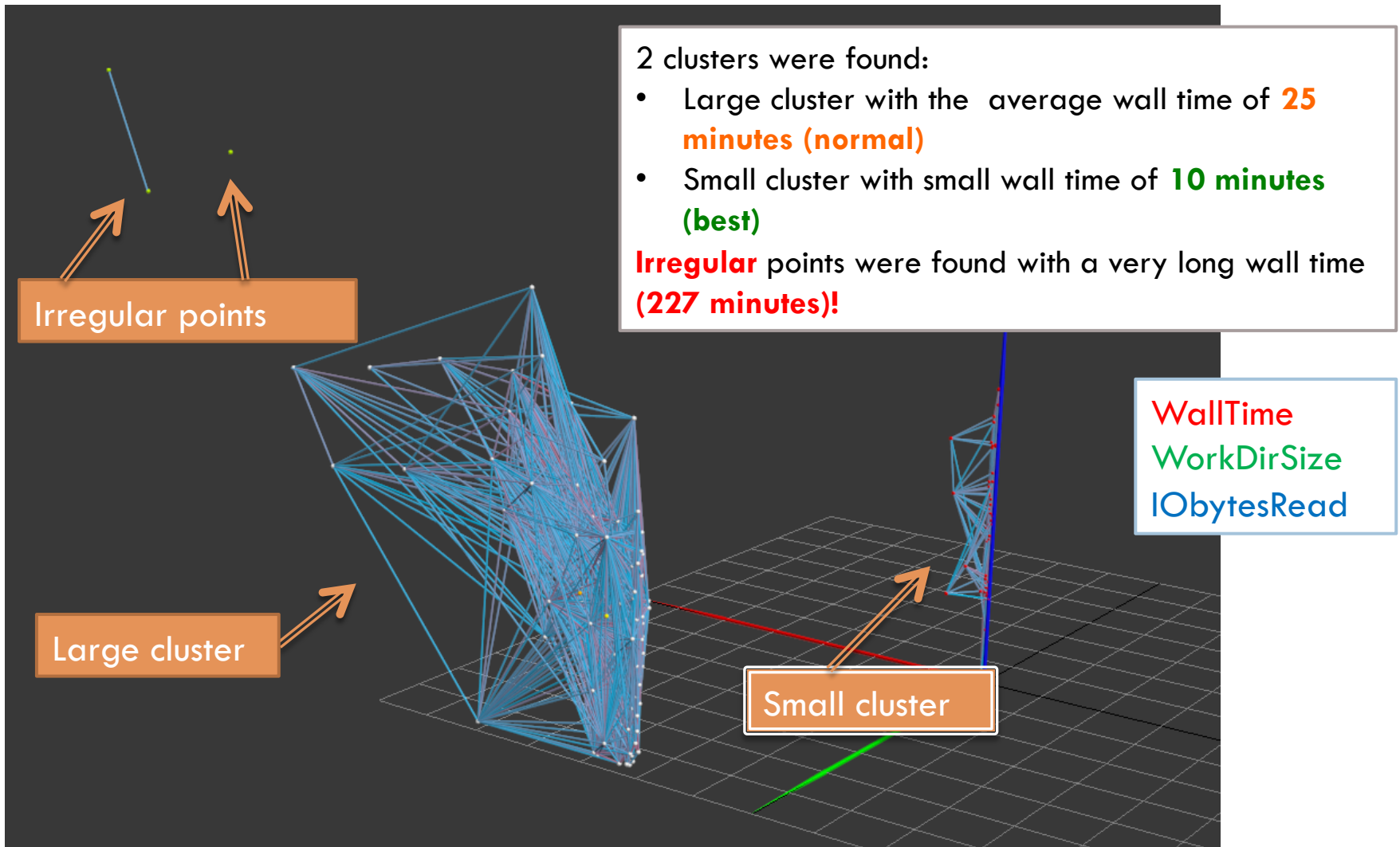


attributes	importance
cpu_eff	0.712740
IBytesReadRate	0.184547
cpuconsumptiontime	0.034778
timeSetup	0.016238
timeStageIn	0.009818
IBytesRead	0.009795
workDirSize	0.008707
avgswap	0.008375
inputfilebytes	0.003622
timeStageOut	0.001935

# Clusters and Anomalies

Task №14296407. Site 2

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# Results of cluster analysis. Time & Memory

Task №14296407. Site 2

13

Features	Large cluster	Small cluster	Irregular points
WallTime	25 min	<b>10 min</b>	<b>227 minutes</b>
CPUTime	3,8 min	3,2 min	3,5 min
TimeSetup	36 sec	<b>13 sec</b>	<b>120 sec</b>
TimeStageIn	370 sec	<b>110 sec</b>	356 sec
TimeStageOut	59 sec	<b>33 sec</b>	<b>680 sec</b>
DBTime	20 sec	<b>7 sec</b>	<b>266 sec</b>
QueueTime	32 min	64 min	58 min
AvgRSS	544	544	530
MaxRSS	825	817	814
AvgVmem	1 813	1 731	2 014
MaxVmem	3 041	2 767	3 056

Megabytes

# Results of cluster analysis. IO Memory Metrics

Task №14296407. Site 2

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Features	Large Cluster	Small cluster	Irregular points
<b>Inputfilebytes</b>	300	300	300
<b>Outputfilebytes</b>	600	600	600
<b>IObytesWritten</b>	531	488	568
<b>IObytesRead</b>	1 957	1 704	<b>3 029</b>
<b>IOcharRead</b>	1 088	976	<b>1 581</b>
<b>IOcharWriten</b>	526	484	561
<b>WorkDirSize</b>	600	<b>8</b>	600
<b>IObytesReadRate</b>	3,868	<b>6,716</b>	<b>0,690</b>
<b>IObytesWriteRate</b>	1,068	<b>1,945</b>	<b>0,180</b>
<b>IOcharReadRate</b>	2,146	<b>3,877</b>	<b>0,457</b>
<b>IOcharWriteRate</b>	1,059	<b>1,931</b>	<b>0,180</b>

Megabytes

MB/sec

# Analysis of clusters in the initial dataset

Task №1 4296407. Site 2

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- Metrics of 2 clusters and irregular points were analyzed. The following were found:
  - The CPU time is in the expected range in all clusters and irregular points
  - The amounts of RAM and virtual memory are almost the same in all clusters and irregular points
  - Input and output files sizes are 300 and 600 Mb respectively for all clusters and points
  - Observed input data read much larger than single input file sizes
    - 6 times larger for normal cluster
    - 10 times larger for irregular points
  - Written data is close to the output file size

# Analysis of clusters in the initial datasample

Task №14296407. Site 2

16

- Irregular points have the following peculiar properties (in comparison with the large cluster):
  - timeSetup - 3 times longer
  - timeStageOut - 10 times longer
  - dbTime - 13 times longer
  - QueueTime - twice longer
  - ReadRate - 5 times slower
  - WriteRate - 6 times slower
- The small cluster has the highest rates of data read/write (twice larger than in large cluster) and the shortest wall time
  - Probably it can be connected with the workDirSize, which is the smallest for this cluster
- The amount of read information is a subject to further investigation and analysis. Hypothesis of the reasons could be:
  - Failed jobs on the same site lead to overload of the data streams
  - Input of the data failed and had to start from the beginning



# Conclusions

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- The methodology of data analysis with the combined usage of statistics, machine learning and visual analytics methods was proposed
- The first prototype of interactive visual analytics platform was developed on the basis of 3dsMax
- The developed methodology and visual prototype were applied to the analysis of ATLAS jobs execution

# Future plans

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- Increase the size of investigated data samples
- Enhance numerical features with categorical
- Apply new ATLAS data sources (AGIS, NWS) providing the information about sites and network status during jobs execution
- The development of the visual analytics tools
  - ▣ Extend the application to dynamic data analysis
  - ▣ Use open-source platform (e.g., VTK)

# Acknowledgements

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- This work was supported by RSCF grant №18-71-10003
- Thanks to I. Vukotic, A. Anisenkov, J. Elmsheuser
- Special thanks to A. Klimentov