



Improving Data Center Visibility With Machine Learning

SIParCS 2024

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July 30, 2024

<u>Overview</u>

- Main Objective
 Background
 3. Data
 Machine Learning
 Future Work
- 6. Acknowledgements



Main Objective

Is there a way to effectively predict node failures using machine learning?

What insight can machine learning provide about our supercomputers?





- Very powerful
- Processes large amounts of data
- Casper 121 nodes
- Derecho 2570 nodes
 - Includes 3 CDUs (Cooling Distribution Unit)







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What is a node?

- Individual computers
 - Each have its own "brain" (CPU or GPU)
 - o Own RAM
 - Own Storage Space
- Casper has 121
- Derecho has 2570







Glimpse of the Data

- Timescale Database
 - Time Series Data
 - \circ 20 tables
 - Cheyenne, Casper, Gust, and Derecho
 - o CDU data, node data
- Used SQL in DBeaver to query and export data
- Derecho CDU data & node data
- Casper per node data

DBeaver 24.1.2 - <postgres> Scrip</postgres>)t-22										- U	^
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Casper node data example

Grid	۲	time	eluster	^{aec} dc ▼	ABC host	ecomment	^{ABC} jobs	¹²³ last_state_change_time	¹²³ last_used_time
	1	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5914735.casper-pbs/0, 5913255.casper-pbs/1, 5	٤ 1,678,298,704	1,678,316,193 I
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Ţ.Ţ	3	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5913556.casper-pbs/0, 5911637.casper-pbs/1, 5	9 1,678,151,801	1,678,306,083 I
	4	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5906574.casper-pbs/0, 5906575.casper-pbs/1, 5	9 1,678,165,977	1,678,319,571 I
	5	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5906571.casper-pbs/0, 5914499.casper-pbs/1, 5	s 1,678,31 <mark>4</mark> ,797	1,678,314,796 l
	6	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5916403.casper-pbs/0, 5879489.casper-pbs/1, 5	9 1,678,201,671	1,678,317,481 l
	7	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5879470.casper-pbs/0, 5879640.casper-pbs/1, 5	8 1,678,184,803	1,678,318,748 l
	8	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5914523.casper-pbs/0, 5904807.casper-pbs/1, 5	8 1,678,227,255	1,678,319,872 l
	9	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5906544.casper-pbs/0, 5904977.casper-pbs/1, 5	9 1,678,215,685	1,678,314,534 l
	10	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5916464.casper-pbs/0, 5906524.casper-pbs/1, 5	9 1,678,286,243	1,678, <mark>319,569</mark> I
	11	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5906386.casper-pbs/0, 5912216.casper-pbs/1, 5	9 1,678,179,896	1,678,315,607 l
	12	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5879496.casper-pbs/0, 5904974.casper-pbs/1, 5	9 1,678,17 4 ,142	1,678,319,571 l
	13	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5916488.casper-pbs/0, 5914716.casper-pbs/1, 5	9 1,678,226,021	1,678,318,346 l
	14	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5904284.casper-pbs/0, 5912011.casper-pbs/1, 5	9 1,678,302,095	1,678,316,196 I
	15	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5916431.casper-pbs/0, 5879494.casper-pbs/1, 5	9 1,677,816,920	1,678,318,274 l
	16	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5894303.casper-pbs/0, 5914053.casper-pbs/1, 5	8 1,678,313,511	1,678,313,508 l
	17	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5914061.casper-pbs/0, 5894242.casper-pbs/1, 5	8 1,677,516,397	1,678,315,529 l
	18	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5879578.casper-pbs/0, 5916407.casper-pbs/1, 5	9 1,678,298,237	1,678,318,307 I
	19	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5914265.casper-pbs/0, 5906356.casper-pbs/1, 5	9 1,678,311,770	1,678,317,307 I
	20	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5906383.casper-pbs/0, 5904952.casper-pbs/1, 5	9 1,678,226,393	1,678,318,339 I
	21	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	[NULL]	1,677,881,426	1,678,280,347 l
ord	22	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5904953.casper-pbs/0, 5914215.casper-pbs/1, 5	9 1,677,861,356	1,678,315,339 l
Sec	23	2023-03-08 23:59:31.000	cr	NWSC	casper-pbs	[NULL]	5911675.casper-pbs/0, 5914228.casper-pbs/1, 5	9 1,678,226,192	1,678,319,951 I



Derecho CDU data example

	🤊 time 🔹	ehassis	nost 🔹	nec rack	¹²³ CoolingSubsystem0ACInputFrequency	¹²³ CoolingSubsystem0ACInputLine1Current	¹²³ CoolingSubsystem0ACInputLir
1	2023-08-28 23:58:04.000	c1	x1100c1	x1100	60	10.1	
2	2023-08-28 23:58:04.000	c1	x1000c1	x1000	60	16	
3	2023-08-28 23:56:02.000	c1	x1007c1	x1007	60	16.5	
4	2023-08-28 23:56:02.000	c1	x1100c1	x1100	60	10.1	
5	2023-08-28 23:56:02.000	c1	x1000c1	x1000	60	16.1	
6	2023-08-28 23:54:06.000	c1	x1100c1	x1100	60	10	
7	2023-08-28 23:52:03.000	c1	x1007c1	x1007	60	16.6	
8	2023-08-28 23:52:03.000	c1	x1000c1	x1000	60	16	
9	2023-08-28 23:52:02.000	c1	x1100c1	x1100	60	10.1	
10	2023-08-28 23:50:04.000	c1	x1000c1	x1000	60	15.9	
11	2023-08-28 23:50:03.000	c1	x1100c1	x1100	60	10	
12	2023-08-28 23:50:03.000	c1	x1007c1	x1007	60	16.5	
13	2023-08-28 23:48:04.000	c1	x1100c1	x1100	60	10.1	
14	2023-08-28 23:48:04.000	c1	x1000c1	x1000	60	16	
15	2023-08-28 23:48:04.000	c1	x1007c1	x1007	60	16.5	
16	2023-08-28 23:46:05.000	c1	x1100c1	x1100	60	10	
17	2023-08-28 23:46:04.000	c1	x1007c1	x1007	60	16.5	
18	2023-08-28 23:46:04.000	c1	x1000c1	x1000	60	16	
19	2023-08-28 23:44:07.000	c1	x1007c1	x1007	60	16.6	
20	2023-08-28 23:44:07.000	c1	x1100c1	x1100	60	9.9	
21	2023-08-28 23:44:06.000	c1	x1000c1	x1000	60	16	
22	2023-08-28 23:42:06.000	c1	x1007c1	x1007	60	16.8	
23	2023-08-28 23:42:06.000	c1	x1000c1	x1000	60	16.1	



K-Means Clustering Model Algorithm







- Used to find optimal "k" or clusters
- Elbow "bends" at around
 3





- x1100 reporting 0 for data
- Discovered broken sensor
- 291 points
- Outlet Primary Pressure pressure of the fluid when it exits the cdu and enters the primary cooling loop
- Inlet and Outlet Temp Temp of the liquid as it enters and exits system



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- Chose 3 clusters
- Elbow "bends" at around 3





- Excluded x1100
- Actuator allows water to flow in
- Filter Secondary Pressure -Pressure of cooling fluid
- One CDU rack was misconfigured



K-Means Graphs-Casper



- Chose 4 as optimal "k"
- Could possibly have chosen 2



K-Means Graphs-Casper



- Sept 6-15 2023
- Most ask for max amount of memory
- Most nodes are HPC nodes
- Purple (diamond) cluster is specialized nodes



- Inspired by the human brain
- Neurons receive inputs
- Learns by changing the weights between neurons
- Efficient with anomaly detection, complex data, can be trained on historical data



https://www.researchgate.net/figure/Simple-neural-network-diagram_fig1_332158639





 First model Derecho CDU data Model never predicted 0 							
Metric	Value						
Mean Absolute Error	0.012361268613487481						
Mean Squared Error	0.006910000116743188						
Root Mean Squared Error	0.08312641046468437						
R-squared	-0.0003095865249633789						



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Casper Model:

Parameter	Value					
Window size	50.0					
Batch size	16.0					
Epochs	50.0					
Mean Absolute Error	0.008267107579070884					
Mean Squared Error	0.008267107579070884					
Root Mean Squared Error	0.09092363597586099					
R-squared	0.523836128720933					

Derecho Model:

Parameter	Value					
Window size	50.0					
Batch size	16.0					
Epochs	50.0					
Mean Absolute Error	0.003593501030048069					
Mean Squared Error	0.003593501030048069					
Root Mean Squared Error	0.05994581745249679					
R-squared	0.8053383024007601					



https://www.researchgate.net/figure/Simple-neural-network-diagram_fig1_332158639



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Heat Maps

- last_state_change_time first for both machines
 - May be resolving nodes too quickly
- resources_assigned towards bottom for Casper but top for Derecho
 - Possibly because Casper is more heterogeneous

Casper

Derecho

Feature	Importance				
Hast_state_change_time	20.50%				
resources_available.mem	19.18%				
resources_available.ncpus	18.73%				
last_used_time	16.28%				
resources_available.vmem	8.72%				
resources_assigned.mem	7.60%				
resources_assigned.ncpus	5.43%				
resources_available.ngpus	3.56%				

Feature	Importance	
<pre> last_state_change_time</pre>	43.23%	
last_used_time	30.23%	
resources_assigned.ncpus	9.62%	
resources_assigned_mem	9.11%	
resources_avail_mem	2.76%	
resources_avaiable_vmem	2.43%	
resources_available.ncpus	1.65%	
resources_available.ngpus	0.97%	



Heat Maps

Derecho:

resources_assigned.ncpus -	1	0.75	0.39	0.28	0.18	-0.42	-0.42	0.42	-0.42	- 1.00
resources_assigned_mem -	0.75	1	0.42	0.28	0.2	-0.087	-0.087	0.087	-0.087	- 0.75
avail -	0.39	0.42	1	0.68	0.43	-0.019	-0.019	0.019	-0.019	- 0.50
last_state_change_time -	0.28	0.28	0.68	1	0.73	-0.022	-0.022	0.022	-0.022	- 0.25
last_used_time -	0.18	0.2	0.43	0.73	1	-0.036	-0.036	0.036	-0.036	- 0.00
resources_avail_mem -	-0.42	-0.087	-0.019	-0.022	-0.036	1	1	-1	1	0.25
resources_avaiable_vmem -	-0.42	-0.087	-0.019	-0.022	-0.036	1	1	-1	1	0.50
resources_available.ncpus -	0.42	0.087	0.019	0.022	0.036	-1	-1	1	-1	0.75
resources_available.ngpus -	-0.42	-0.087	-0.019	-0.022	-0.036	1	1	-1	1	- 1.00
	resources_assigned.ncpus -	resources_assigned_mem -	avail -	last_state_change_time -	last_used_time -	resources_avail_mem -	resources_avaiable_vmem -	resources_available.ncpus -	resources_available.ngpus -	1.00

20

Casper:

										10
resources_assigned.ncpus -	1	0.26	0.12	0.11	0.12	-0.078	-0.21	-0.2	-0.05	- 1.0
resources_assigned.mem -	0.26	1	0.16	0.14	0.15	0.14	-0.1	-0.41	-0.27	- 0.8
avail -	0.12	0.16	1	0.032	0.085	0.16	0.055	0.052	0.053	- 0.6
last_state_change_time -	0.11	0.14	0.032	1	0.96	0.016	-0.064	-0.13	0.0048	- 0.4
last_used_time -	0.12	0.15	0.085	0.96	1	0.0076	-0.06	-0.061	-0.049	0.1
resources_available.mem -	-0.078	0.14	0.16	0.016	0.0076	1	0.85	0.48	0.51	- 0.2
resources_available.vmem -	-0.21	-0.1	0.055	-0.064	-0.06	0.85	1	0.72	0.35	- 0.0
resources_available.ngpus -	-0.2	-0.41	0.052	-0.13	-0.061	0.48	0.72	1	0.28	0.2
resources_available.ncpus -	-0.05	-0.27	0.053	0.0048	3-0.049	0.51	0.35	0.28	1	0.4
	resources_assigned.ncpus -	resources_assigned.mem -	avail -	last_state_change_time -	last_used_time -	resources_available.mem -	resources_available.vmem -	resources_available.ngpus -	resources_available.ncpus -	



Casper Model:

Parameter	Value						
Window size	50.0						
Batch size	16.0						
Epochs	50.0						
Mean Absolute Error	0.006460301480735768						
Mean Squared Error	0.006460301480735768						
Root Mean Squared Error	0.08037600065153633						
R-squared	0.6207334316575936						

	Value	
Window size	50.0	
Batch size	16.0	
Epochs	50.0	
Mean Absolute Error	0.003933516897455215	
Mean Squared Error	0.003933516897455215	
Root Mean Squared Error	0.06271775583879907	
R-squared	0.7869194775815369	

Derecho Model:



Confusion Matrices

Casper Model:



Derecho Model:



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22

- 140000

- 120000

- 100000

- 80000

- 60000

- 40000

- 20000

463

147044

Predicted Positive

Future Work

- Use more heat maps
- Group nodes by specific type
- Create my own database for indexing
 - Combining data from other tables was challenging because of not matching times

[™] select * from pbs_no where tim [™] Enter a SQL expression to filter re								
Grid	۲	🥑 time 🔪 🔹	eluster	^{ABC} dc ▼	^{ABC} host ▼			
▦	1	2024-07-23 21:14:01.000	de	NWSC	desched1			
ext	2	2024-07-23 21:14:01.000	de	NWSC	desched1			
÷T T	3	2024-07-23 21:14:01.000	de	NWSC	desched1			
	4	2024-07-23 21:14:01.000	de	NWSC	desched1			
	5	2024-07-23 21:14:01.000	de	NWSC	desched1			
	6	2024-07-23 21:14:01.000	de	NWSC	desched1			
T	7	2024-07-23 21:14:01.000	de	NWSC	desched1			
	8	2024-07-23 21:14:01.000	de	NWSC	desched1			
	9	2024-07-23 21:14:01.000	de	NWSC	desched1			
oro	10	2024-07-23 21:14:01.000	de	NWSC	desched1			

pur	۲	🤊 time	ehassis	nec host
∄	1	2024-07-23 21:14:02.000	c1	x1000c1
ext	2	2024-07-23 21:14:02.000	c1	x1100c1
1 10	3	2024-07-23 21:14:02.000	c1	x1007c1
	4	2024-07-23 21:13:02.000	c1	x1000c1
	5	2024-07-23 21:13:02.000	c1	x1100c1
	6	2024-07-23 21:13:02.000	c1	x1007c1
	7	2024-07-23 21:12:02.000	c1	x1000c1
	8	2024-07-23 21:12:02.000	c1	x1007c1
	9	2024-07-23 21:12:02.000	c1	x1100c1
Sor	10	2024-07-23 21:11:02.000	c1	x1100c1



Thank you!



- My mentors Ben Matthews and Jenett Tillotson and the rest of the HPCRD team
- Virginia Do, Jerry Cyccone, Jessica Wang, Eva Sosoo, Ben Fellman and the rest of the CISL team
- All of the SIParCS interns for a fun summer!

