Corl8: A System for Analyzing Diagnostic Measures in Wireless Sensor Networks

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Abstract

Overview

- Introduction
- Design and Implementation of Corl8
- Use Cases
- Results
- Demo
- Conclusions and Future Work

What are wireless sensor networks?

Wireless Sensor Network Restrictions

- Must require minimal maintenance
- Must be able to react to and recover from failures
- Must function with limited storage
- Must function with limited power
- Must function with limited computational abilities

Motivation

- It is important to debug wireless sensor networks while using as few resources as possible
- Our network transmits diagnostic measures
- Preliminary work – graphs of measures
- Phase 1 – Corl8 batch mode
- Phase 2 – Corl8 web interface

Problem Statement

- Programmers want to remove errors
- Debugging tools come with a cost
- Simply transmitting diagnostic measures provides some knowledge but little information on relationships
- Understanding relationships allows problems to be localized more quickly

Sympathy

- Designed to be deployed in tree-based, multi-hop topologies
- Assigns each failure a localized source (*self*, *path*, or *sink*)
- Monitors network traffic and node metrics
- Introduces <= 31% overhead
- We work to avoid system modifications and isolate failures to specific components of a sensor node

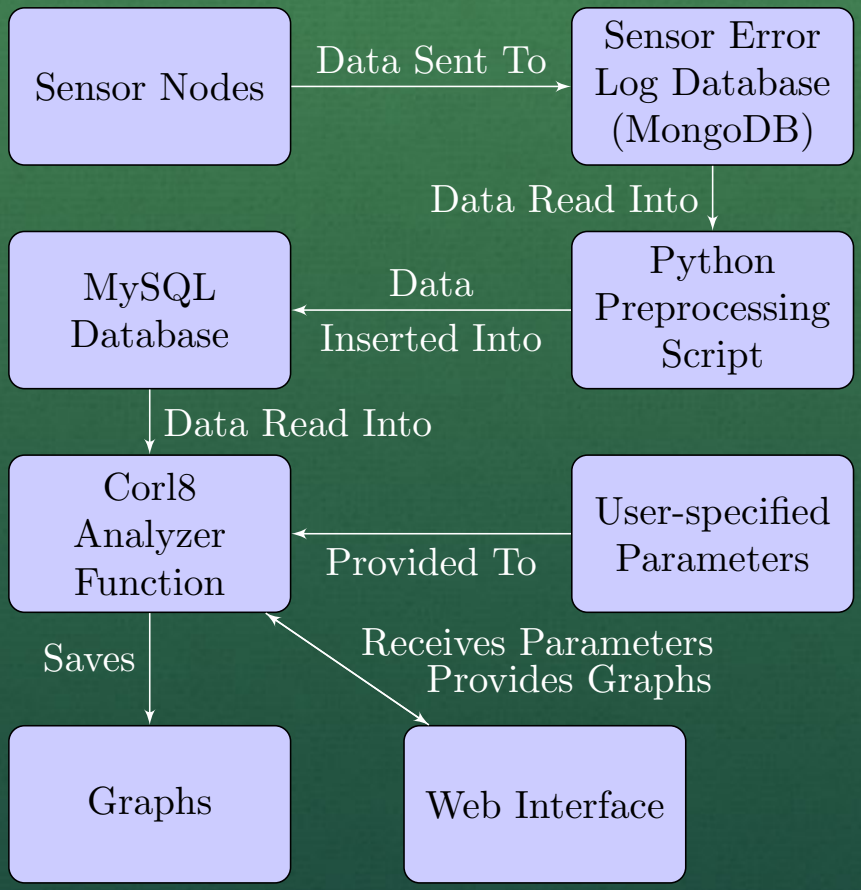
1. Nithya Ramanathan, Kevin Chang, Rahul Kapur, Lewis Girod, Eddie Kohler, and Deborah Estrin. Sympathy for the sensor network debugger. In Proceedings of the 3rd International Conference on Embedded Networked Sensor Systems, SenSys '05, pages 255–267, New York, NY, USA, 2005. ACM.
2. Nithya Ramanathan, Eddie Kohler, and Deborah Estrin. Towards a debugging system for sensor networks. Int. J. Netw. Manag., 15(4): 223–234, July 2005.

Emstar

- Favors ease of use and modularity over efficiency
- EmView, a component for network visualization, must specifically request updates
- Must run on multi-process "micro-server" style nodes
- Not applicable to systems with limited resources
- Relies on stored logs and concurrent processes rather than transmitting information beforehand

1. Lewis Girod, Jeremy Elson, Alberto Cerpa, Thanos Stathopoulos, Nithya Ramanathan, and Deborah Estrin. Emstar: A software environment for developing and deploying wireless sensor networks. In USENIX 2004 Annual Technical Conference, pages 283–296, 2004.
2. Lewis Girod, Nithya Ramanathan, Jeremy Elson, Thanos Stathopoulos, Martin Lukac, and Deborah Estrin. Emstar: A software environment for developing and deploying heterogeneous sensor-actuator networks. ACM Trans. Sen. Netw., 3(3), August 2007.

Corl8 Design



Corl8 MySQL Table Structure

Column Name	Column Type	Key
id	int(11)	primary key
diagnostic	varchar(100)	key
pmin	decimal(18,9)	
pradio	decimal(18,9)	
psample	decimal(18,9)	
raw	decimal(18,9)	
time	datetime	key
device	varchar(100)	key

Populating MySQL with Python

- Reads from MongoDB and inserts into MySQL
- Computes per minute, sample attempt, and transmission attempt data
- Adjusts data for reboots
- Parameterized to allow use with different databases
- Customization will be necessary for use with other wireless sensor networks

R Analyzer Overview

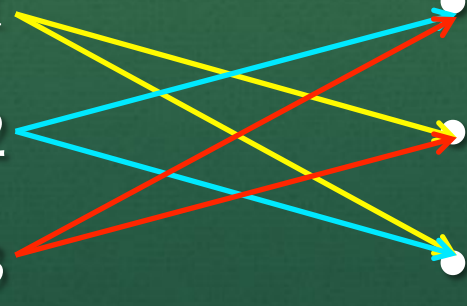
Node

Independent Measure

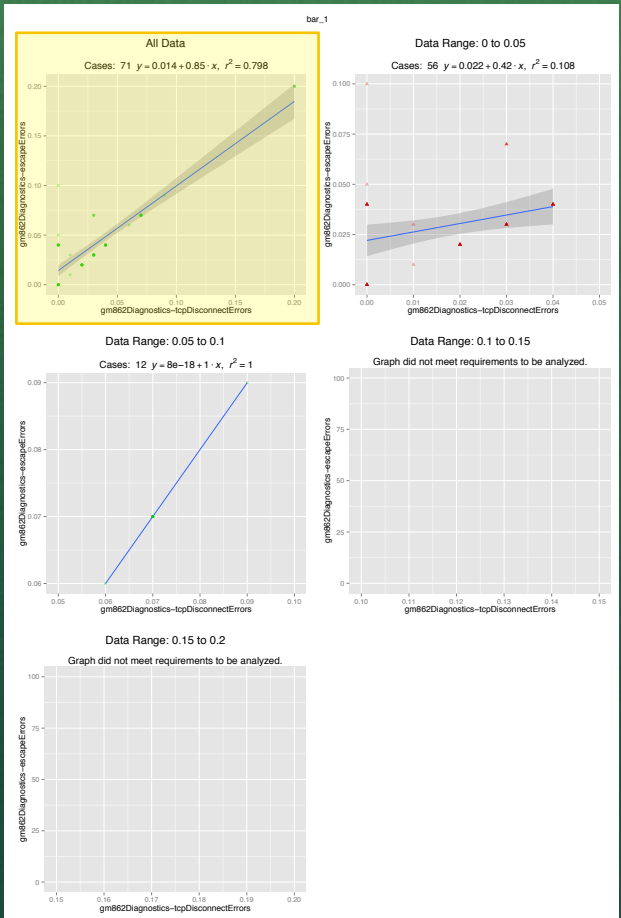
- Diagnostic 1
- Diagnostic 2
- Diagnostic 3

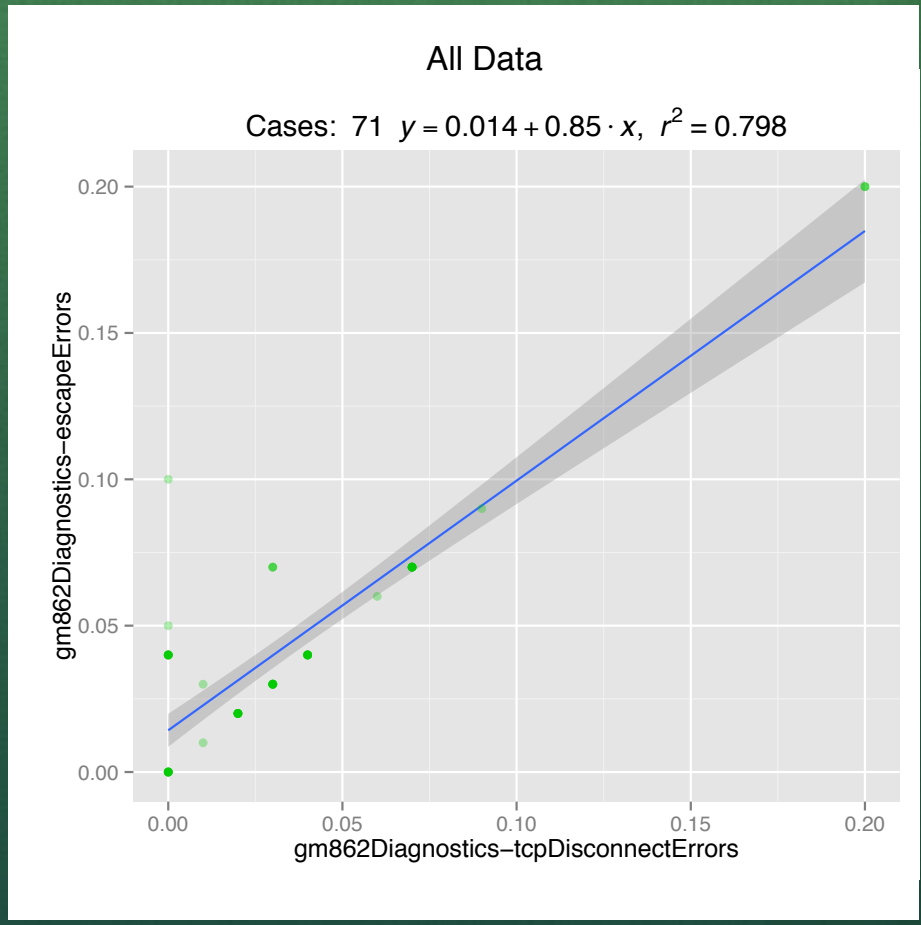
Dependent Measure

- Diagnostic 1
- Diagnostic 2
- Diagnostic 3



Sample Graph Set





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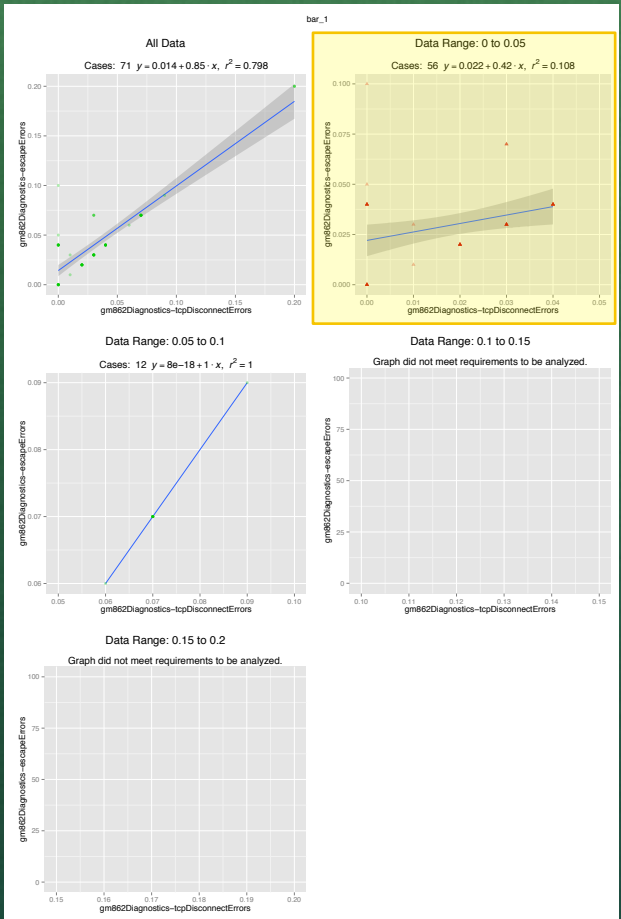

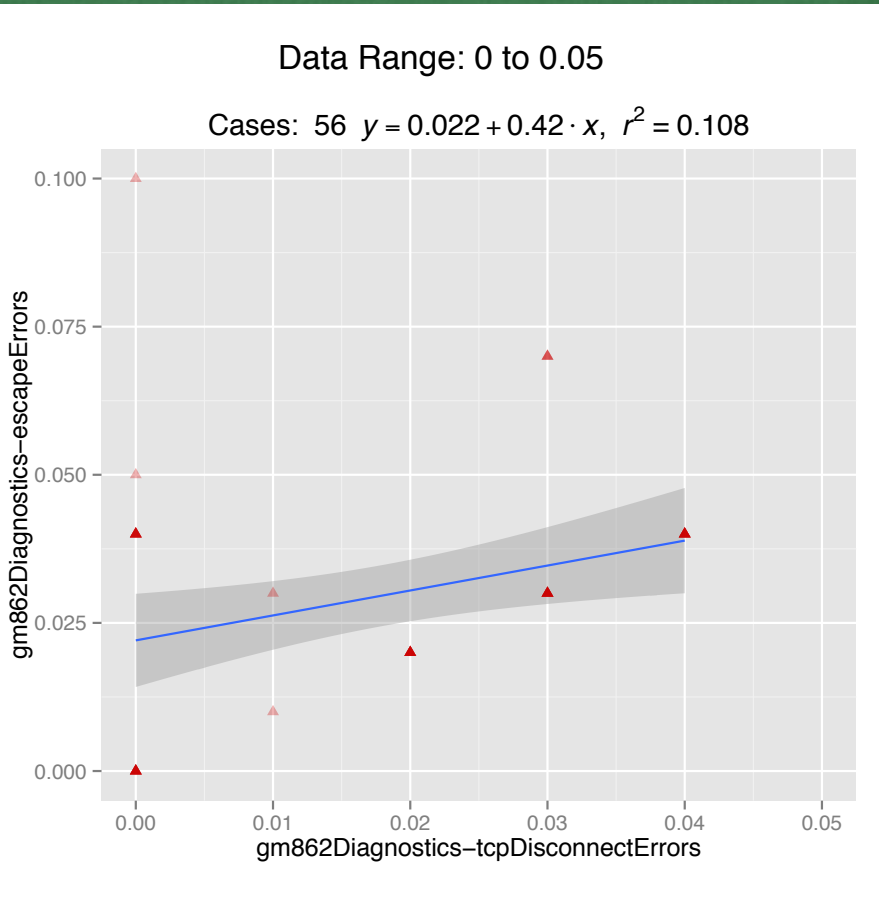

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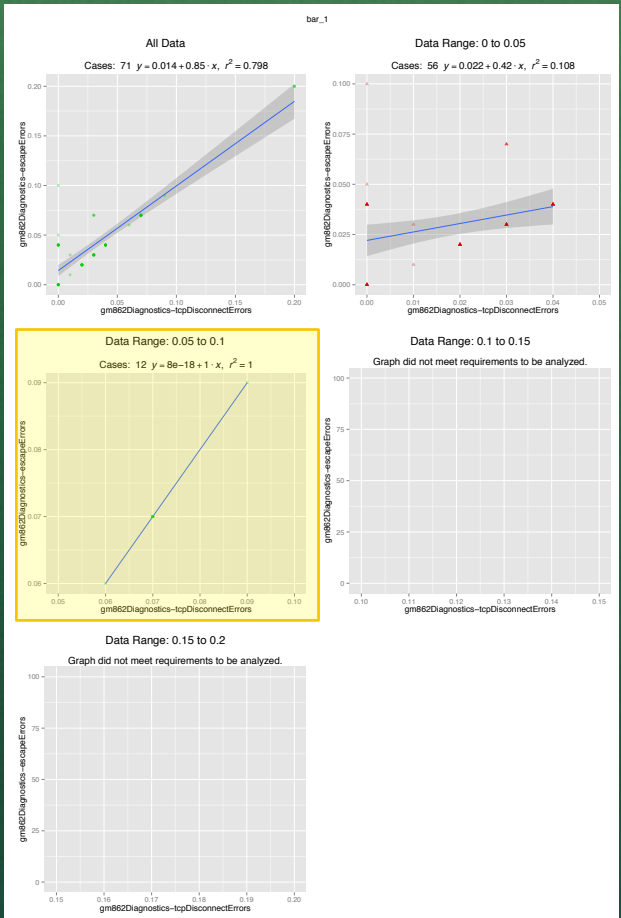

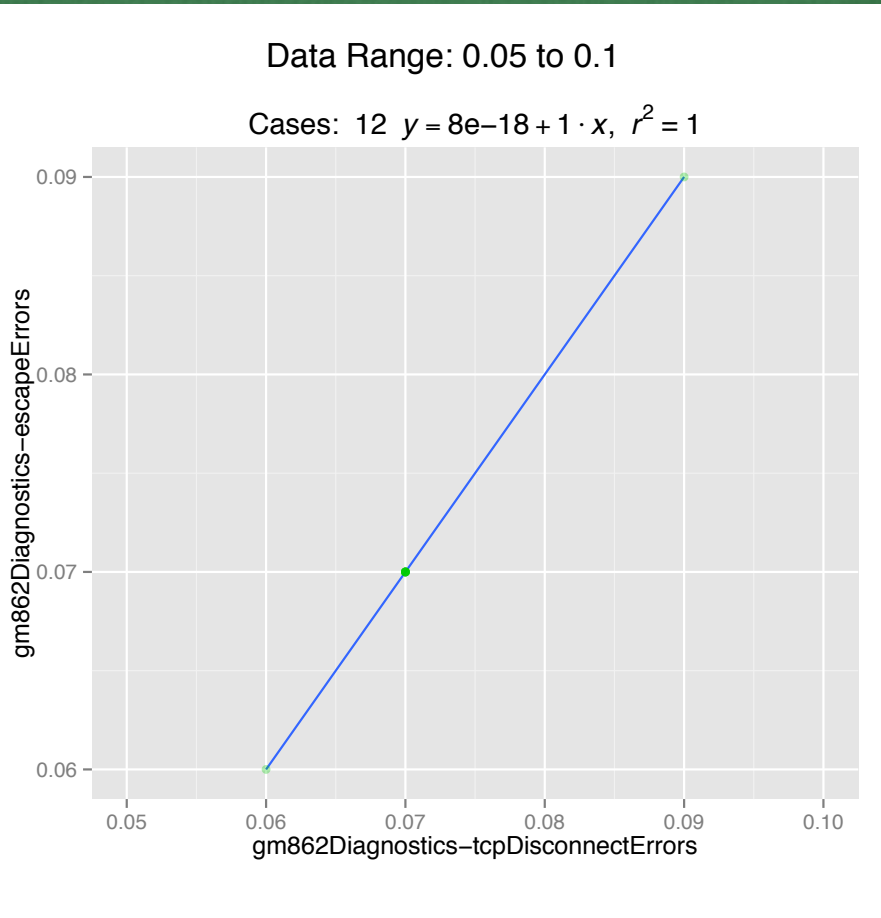

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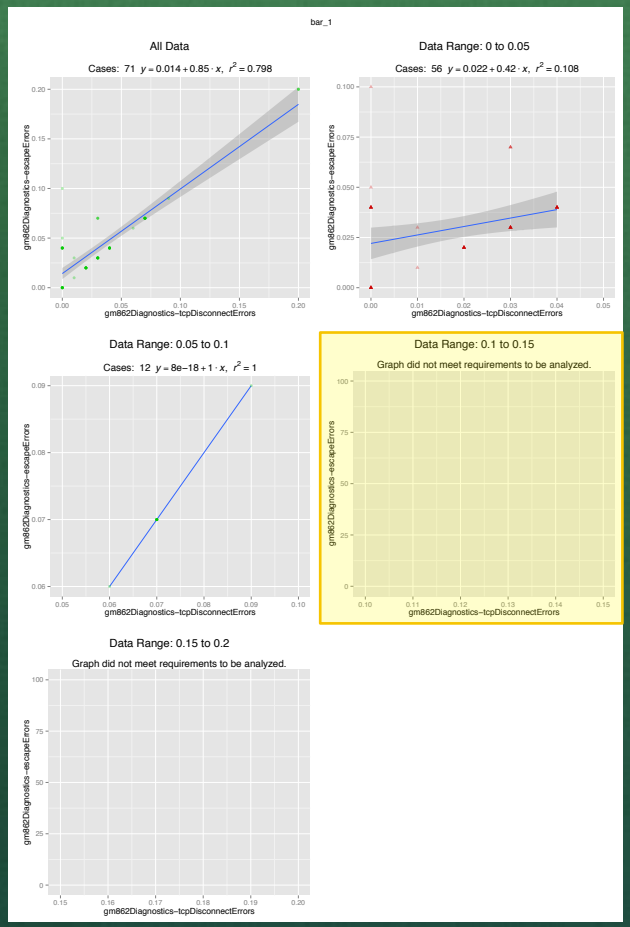

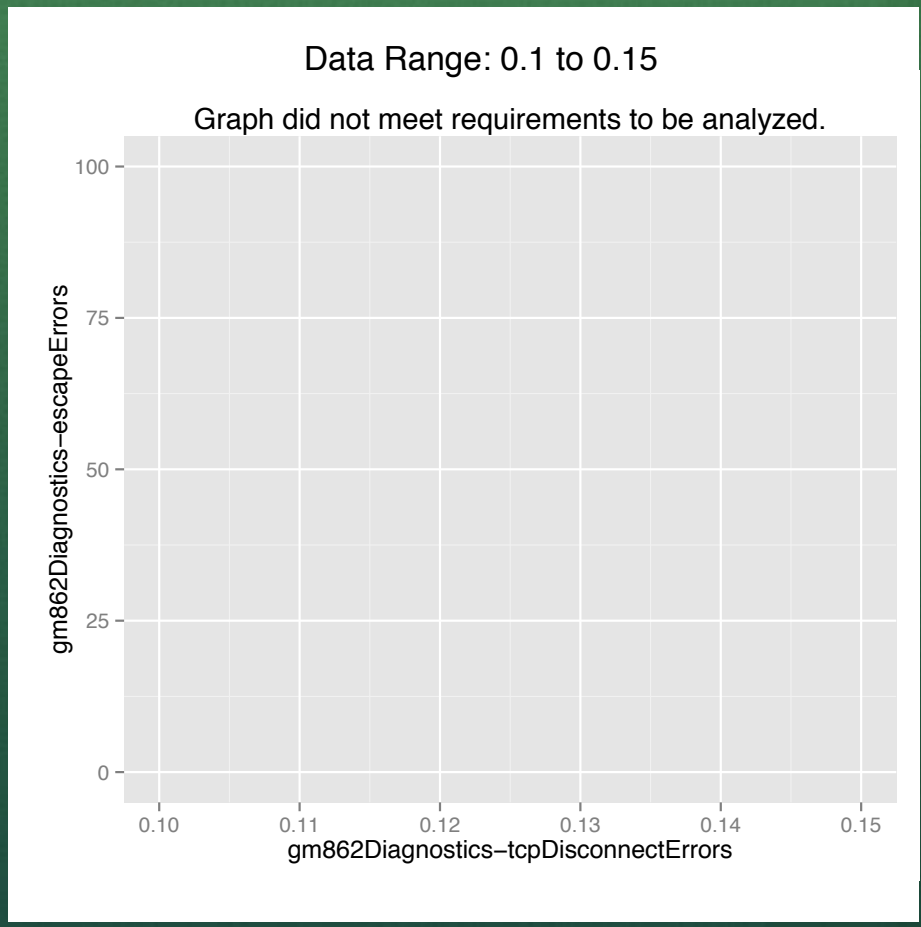

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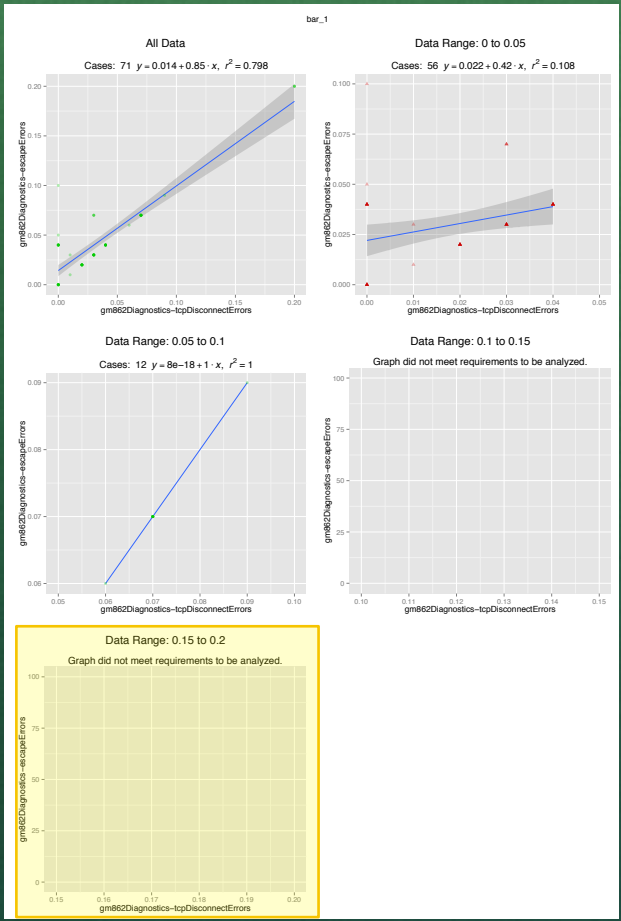
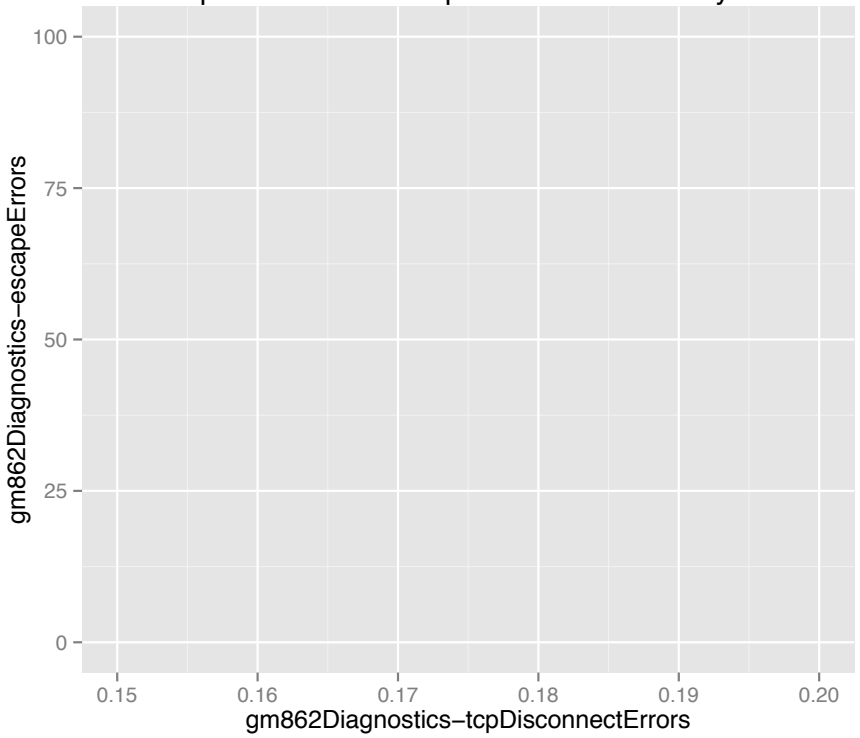
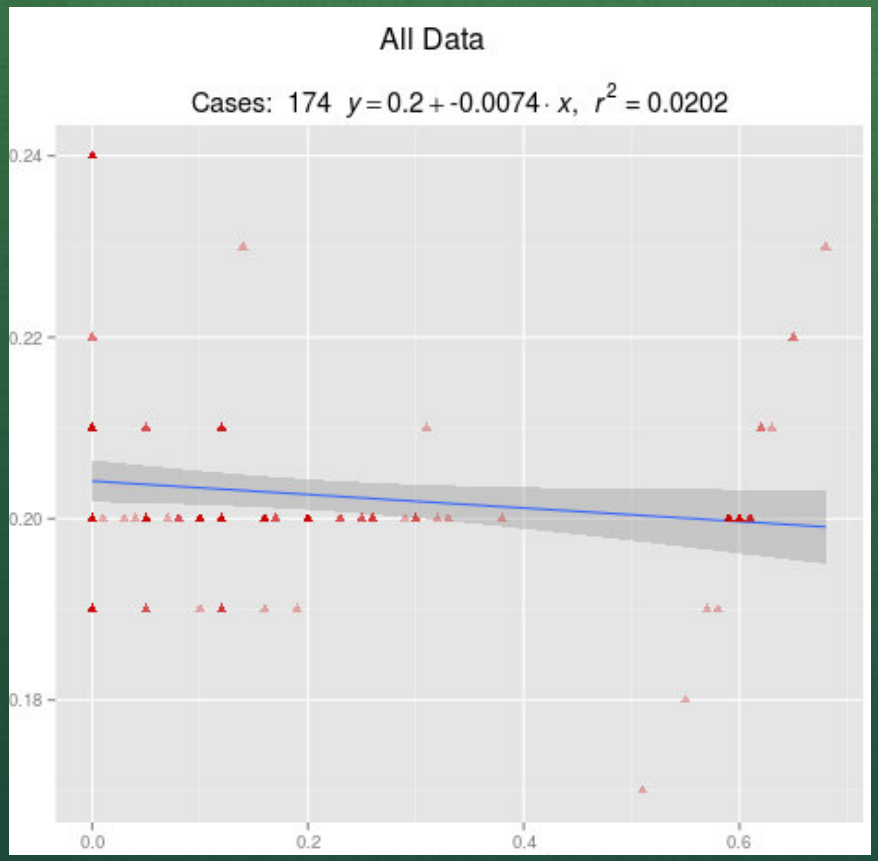




Divisions


All Data
Cases: 174 $y = 0.2 + -0.0074 \cdot x$, $r^2 = 0.0202$
0.24
0.22
0.20
0.18
0.0
0.2
0.4
0.6


Data Range: 0.51 to 0.68
Cases: 35 $y = -0.0096 + 0.35 \cdot x$, $r^2 = 0.938$
0.22
0.20
0.18
0.55
0.60
0.65

R Analyzer Parameters

- device – Device to consider or all
- diagnostics – Diagnostics to analyze or all
- diagCol1 – Data column for X
- diagCol2 – Data column for Y
- threshold – Minimum number of points
- maxDuplicates – Max duplicates of a single point
- round – Decimal places to allow
- minRS – Minimum R-square value for correlation
- minDate and maxDate – Date range for data
- requireSubCor – Require a division to be correlated
- divisions – Number of segments
- divisionThreshold – Minimum points in a segment
- many others….

Analysis Approach

- Linear regression test over the complete set of data
- Repeated linear regression test over each of the divided equal-width segments, if any
- If desired, the user could change these methods

Web Interface

- Allows users to interactively view graph sets
- Users can interactively set many of the analyzer function parameters
- Returns individual graph sets quickly

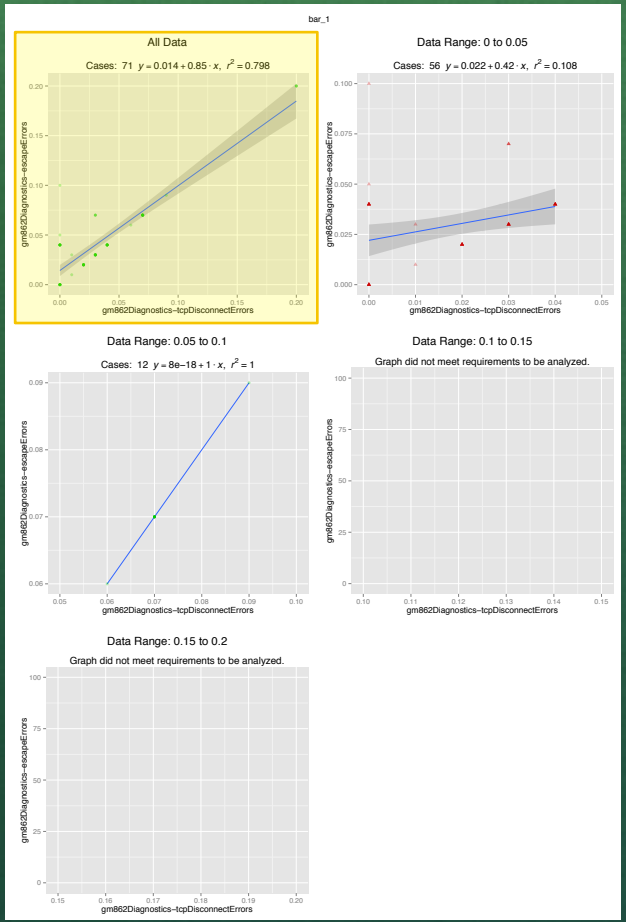
Corl8 Batch Function Use Case

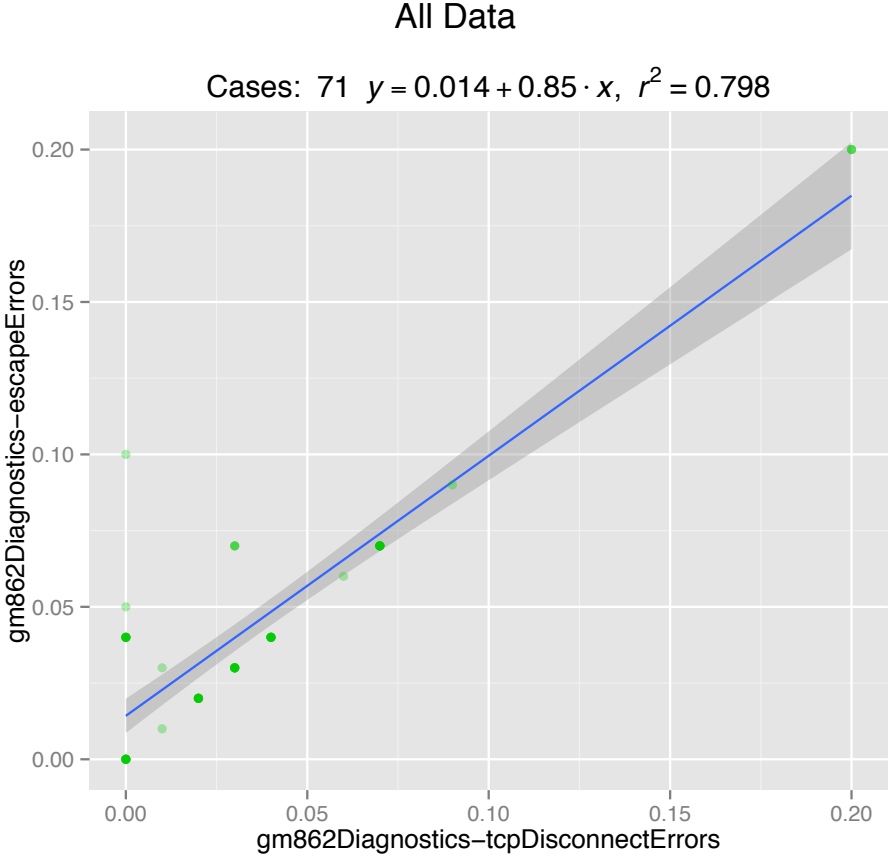
- Over 3 million diagnostic measures from 36 nodes
- About 9 hours running time
- 590 flagged graph sets
- Some graph sets show expected correlations or different views of the same data
- Others give cause for concern
- The default settings met our needs

Corl8 Web Interface Use Case

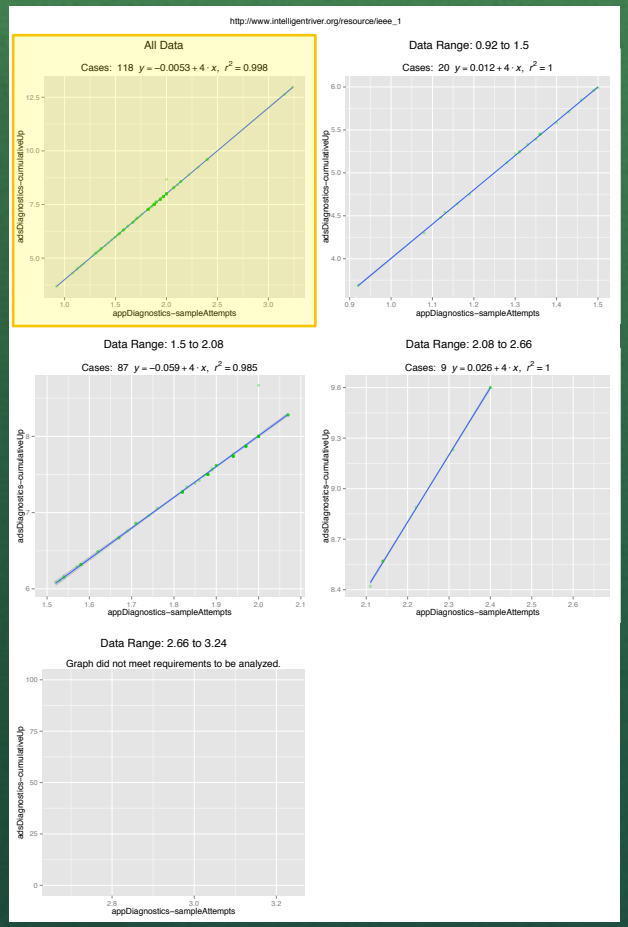
- Faster results
- Explore suspected issues
- Modify search parameters to further investigate
- Investigate the effects of different settings to determine the parameters for the batch function

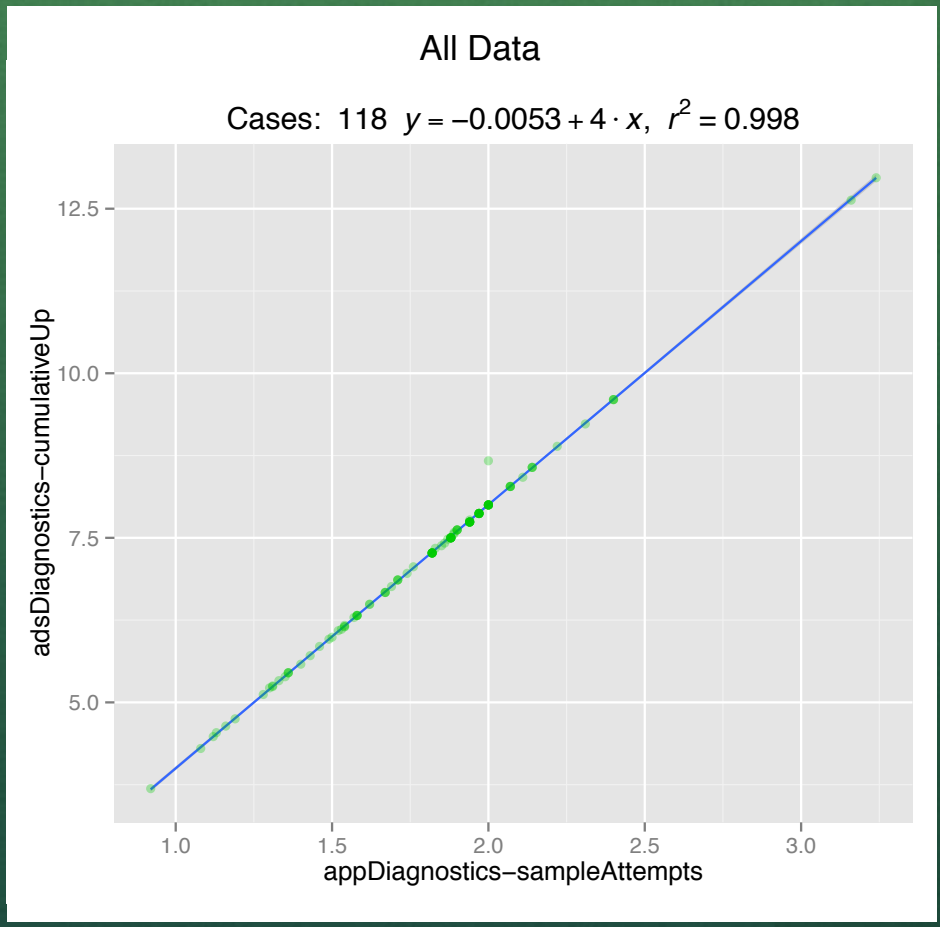
Results
Cellular Modem Faults



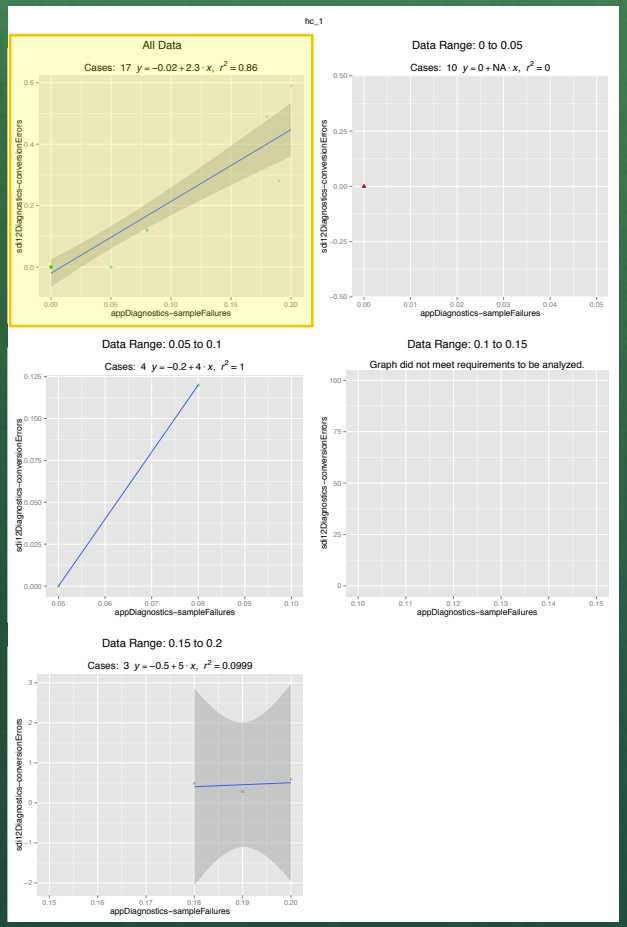


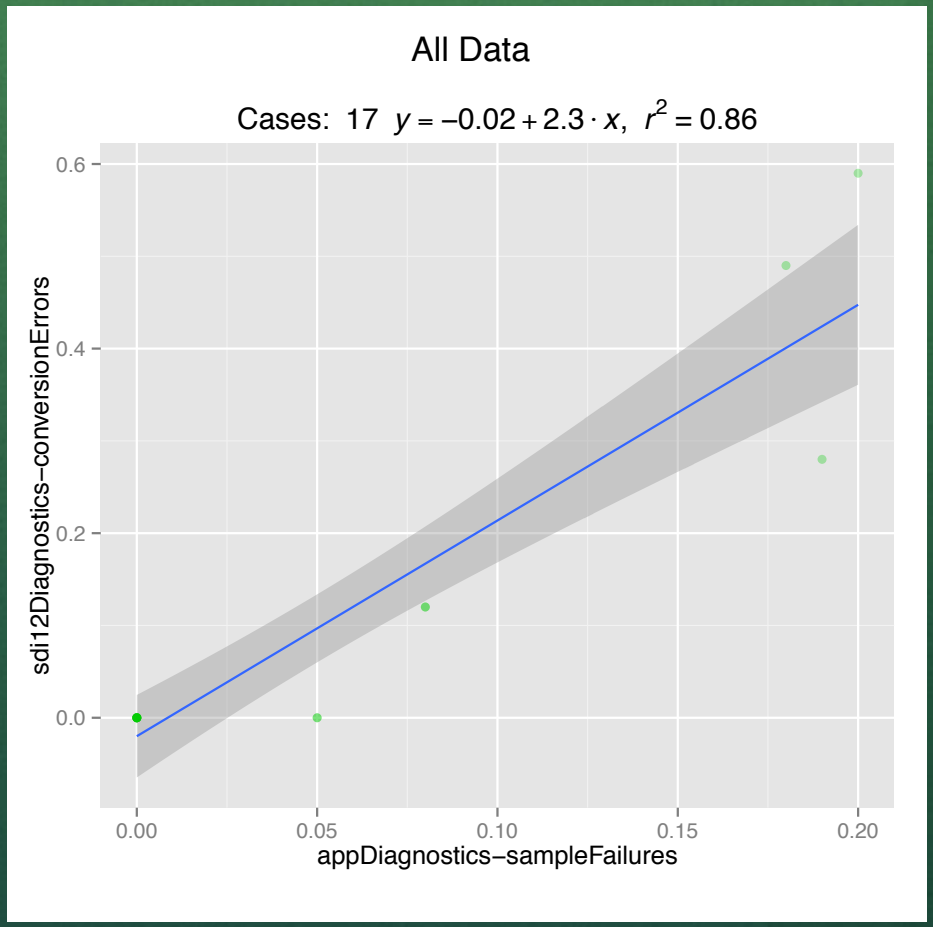
Results - Sample Attempts Versus Node Up-time





Results- Hunnicutt Creek Sampling Problems

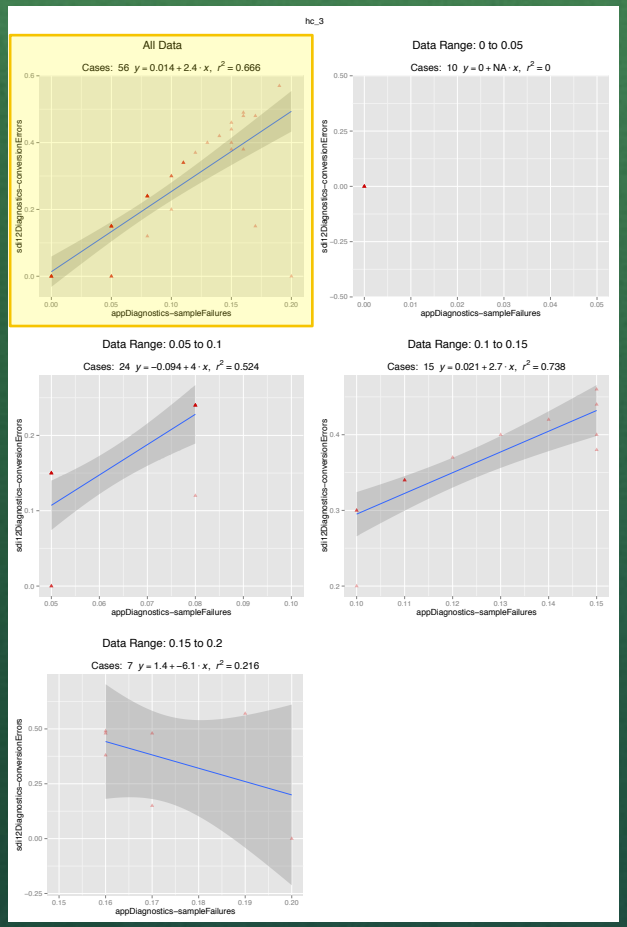


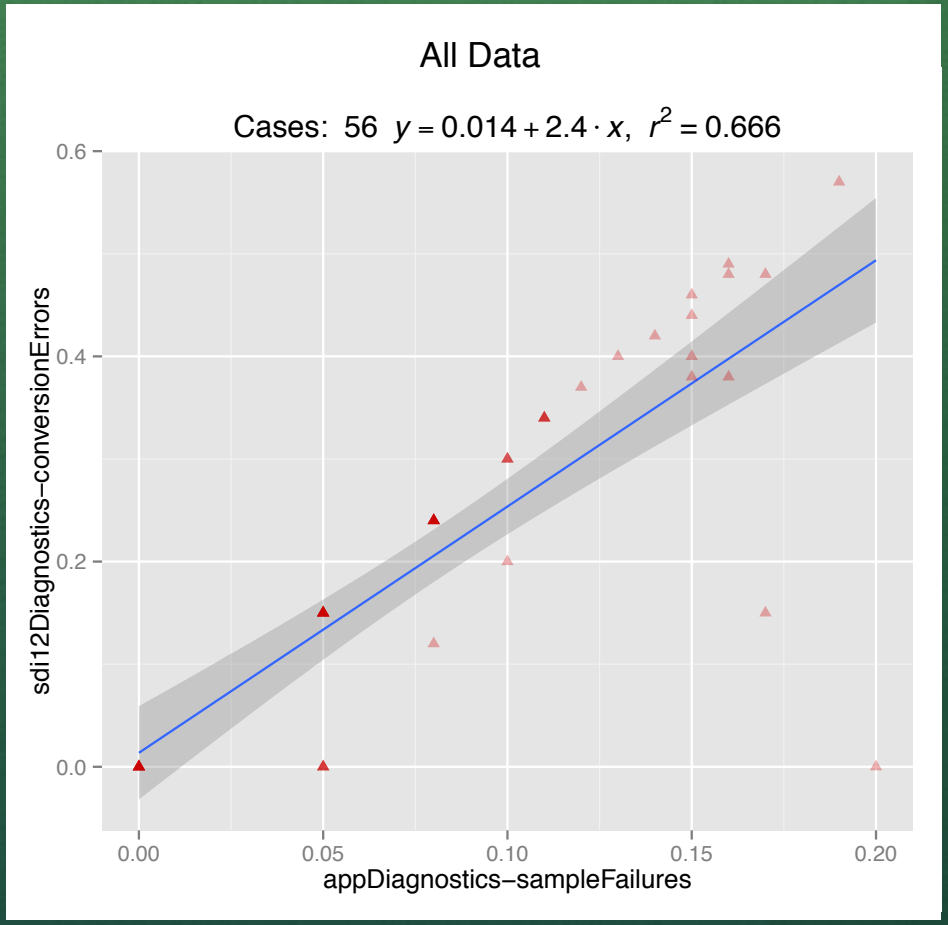


Corl8 Web Interface Demo

- http://130.127.154.200:3838/corl8/

Results - Hunnicutt Creek Sampling Problems





Conclusions

- Corl8 helps developers determine causes of failure by analyzing correlated diagnostic measures
- We avoid add-in network protocols
- Flexibility allows researchers to implement our system with no changes to their network
- Batch mode helps identify unknown faults in a system
- Interactive mode helps investigate suspected faults
- In our tests, Corl8 worked successfully

Future Work

- Expand Corl8 to include observation data
- This will lead to more robust analyses, particularly when environmental factors are suspected
- We also hope this will lead to researchers in other disciplines using Corl8

Questions?