National Aeronautics and Space Administration

DIAGNOSTIC ALGORITHM BENCHMARKING

Scott Poll (NASA Ames Research Center)

Objectives

- Benchmark diagnostic algorithms (DAs) using standardized platform
- Compare performance empirically
- Facilitate research in and maturation of diagnostic technologies

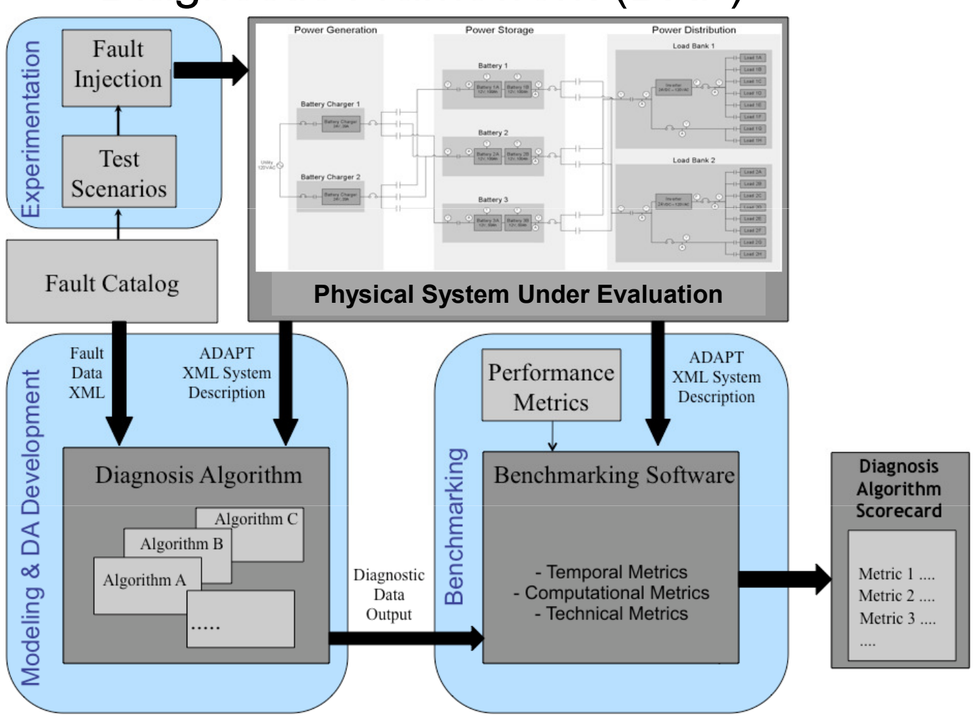
Challenges

- Various diagnostic approaches (expert systems, model-based, data-driven, stochastic)
- Diagnostic algorithms support different operational contexts – difficult to define evaluation criteria

Approach

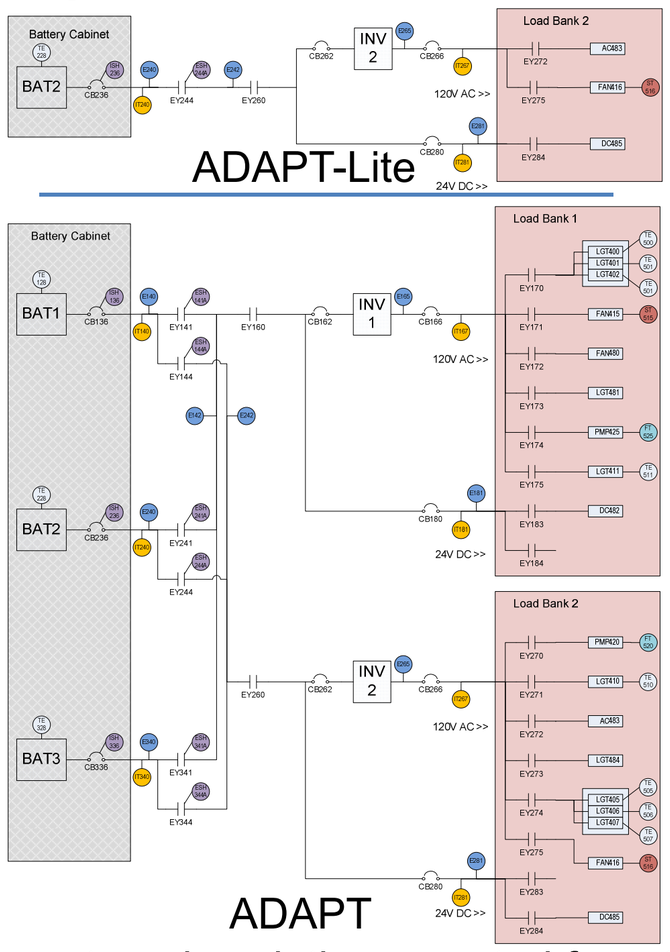
- Acquire nominal and faulty experimental data with known ground truth
- Use standard formats for system description, data, and diagnosis results
- Create software framework to execute diagnostic algorithms and evaluate performance

Diagnostic Framework (DXF)



- High-level representation of physical system description, sensor data, diagnosis output
- Run-time architecture for executing DAs with experimental scenarios
- Evaluation component that evaluates DAs using pre-defined metrics

Implementation



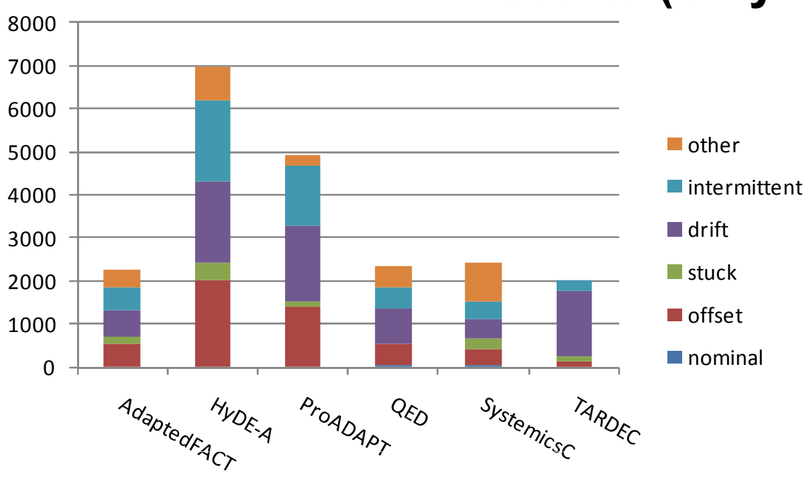
- Two system descriptions created from the ADAPT Electrical Power System testbed
- Archived ~4 minute nominal and faulty scenarios with known ground truth for ADAPT-Lite and ADAPT systems

DXC'10 Diagnostic Problems

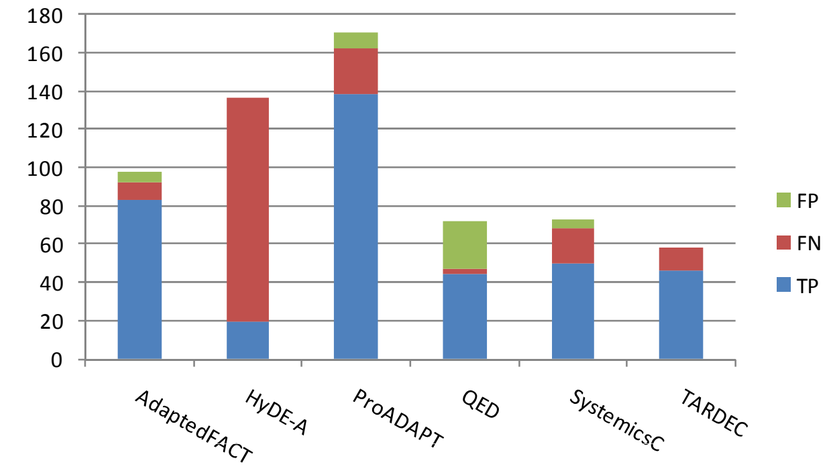
Aspect		DP-I	DP-II
system		ADAPT-Lite	ADAPT
operational scenario		single-string UAS mission	redundant systems UAS mission
diagnostic use case		abort rec.	fault recovery rec.
#comps		25	96
#modes		102	306
initial relay state		closed	open
initial circuit breaker state		closed	closed
nominal mode changes		no	yes
multiple faults		no	yes
fault types	offset	yes	yes
	drift (incipient)	yes	no
	intermittent offset	yes	no

- DXF and ADAPT EPS scenarios used in two diagnostic competitions (DXC'09, DXC'10), hosted by the International Workshop on Principles of Diagnosis
- DXC'10 introduced new challenges: new fault types, reduced sensor set, multiple sample rates

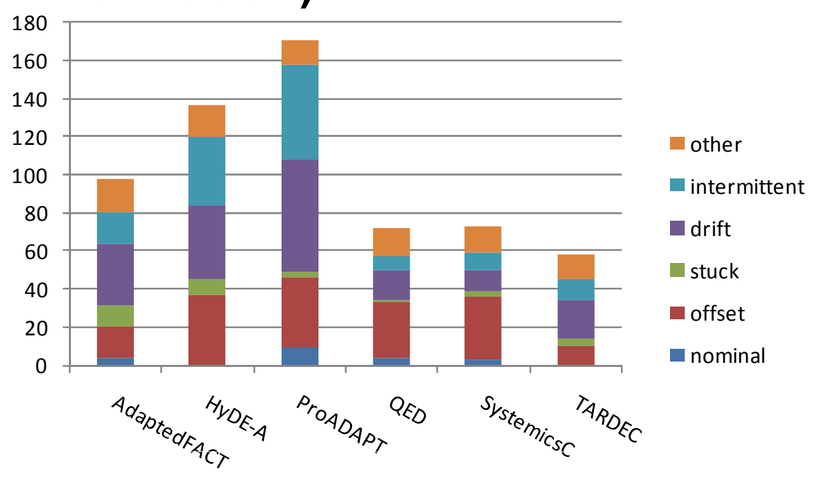
Results (only DXC'10 DP-I shown, see links for more information)



DP-I cost breakdown by scenario fault type



DP-I classification error by scenario detection type



DP-I classification error by scenario fault type

Actual / Case DA rec.	abort	non-abort
abort	0	$c_{mission}$
non-abort	$c_{mission}$ + $c_{vehicle}$	0

$c_{mission}$ = 25, $c_{vehicle}$ = 100

DA	Cost	Rank
AdaptedFACT	2250	2
HyDE-A	6950	6
ProADAPT	4925	5
QED	2350	3
SystemicsC	2400	4
TARDEC	2000	1

By comparison,
DA that always aborts = 2225,
DA that never aborts = 8125,
Minimum possible cost = 0

Metric	Name	Category
M_{fd}	fault detection time	detection
M_{fn}	false negative rate	detection
M_{fp}	false positive rate	detection
M_{da}	scenario detection accuracy	detection
M_{fi}	fault isolation time	isolation
M_{err}	classification errors	isolation
M_{cpu}	CPU load	computation
M_{mem}	memory load	computation

- No DA dominates all metrics
- Real-world system noise, latencies, transients, and coding errors resulted in DA false positives and classification errors

Publications and Data Sets

ADAPT Electrical Power System information, software framework, sample data, test data, results, publications and presentations are available on DASHlink:

- DXC'09: https://c3.ndc.nasa.gov/dashlink/projects/36/
- DXC'10: https://c3.ndc.nasa.gov/dashlink/projects/33/

DA	M_{fd} (s)	M_{fn}	M_{fp}	M_{da}	M_{fi} (s)	M_{err}	M_{cpu}(ms)	M_{mem}(kb)
AdaptedFACT	21.462	0.069	0.040	0.901	151.746	98.000	37189	9656
HyDE-A	27.717	0.873	**0.000**	0.240	29.355	136.030	1550	6463
ProADAPT	15.990	0.179	0.019	0.825	64.711	171.000	6356	4373
QED	**7.307**	**0.015**	0.105	0.882	115.499	71.752	**239**	5364
SystemicsC	9.390	0.134	0.026	0.856	**13.860**	73.000	229057	**3151**
TARDEC	162.638	0.090	**0.000**	**0.922**	162.638	**58.000**	8979	3211

Team: Scott Poll (NASA Ames), Sriram Narasimhan (UARC @ NASA Ames), Tolga Kurtoglu (PARC), David Garcia (PARC), Johan de Kleer (PARC), Alexander Feldman (Delft University of Technology & PARC), Arjan van Gemund (Delft University of Technology)

NASA Aviation Safety Annual Technical Meeting, St. Louis, MO May 10 – 12, 2011