FlexDx: A Reconfigurable Diagnosis Framework

Mattias Krysander, Fredrik Heintz,
Jacob Roll, Erik Frisk ISY/IDA

Introduction

Detecting and isolating multiple faults in a dynamic process is a computationally intense task which typically consists of computing a set of tests and then computing the diagnoses based on the test results. FlexDx is a reconfigurable diagnosis framework which reduces the computational burden by only running the tests that are currently needed. The method selects tests such that the isolation performance of the diagnostic system is maintained. Special attention is given to issues introduced by a reconfigurable diagnosis framework which has to:

- add and remove tests dynamically,
- perform tests on partially historic data, and
- combine synchronous/asynchronous processing.

To handle these issues FlexDx uses DyKnow, a stream-based knowledge processing middleware framework.

The FlexDx Framework

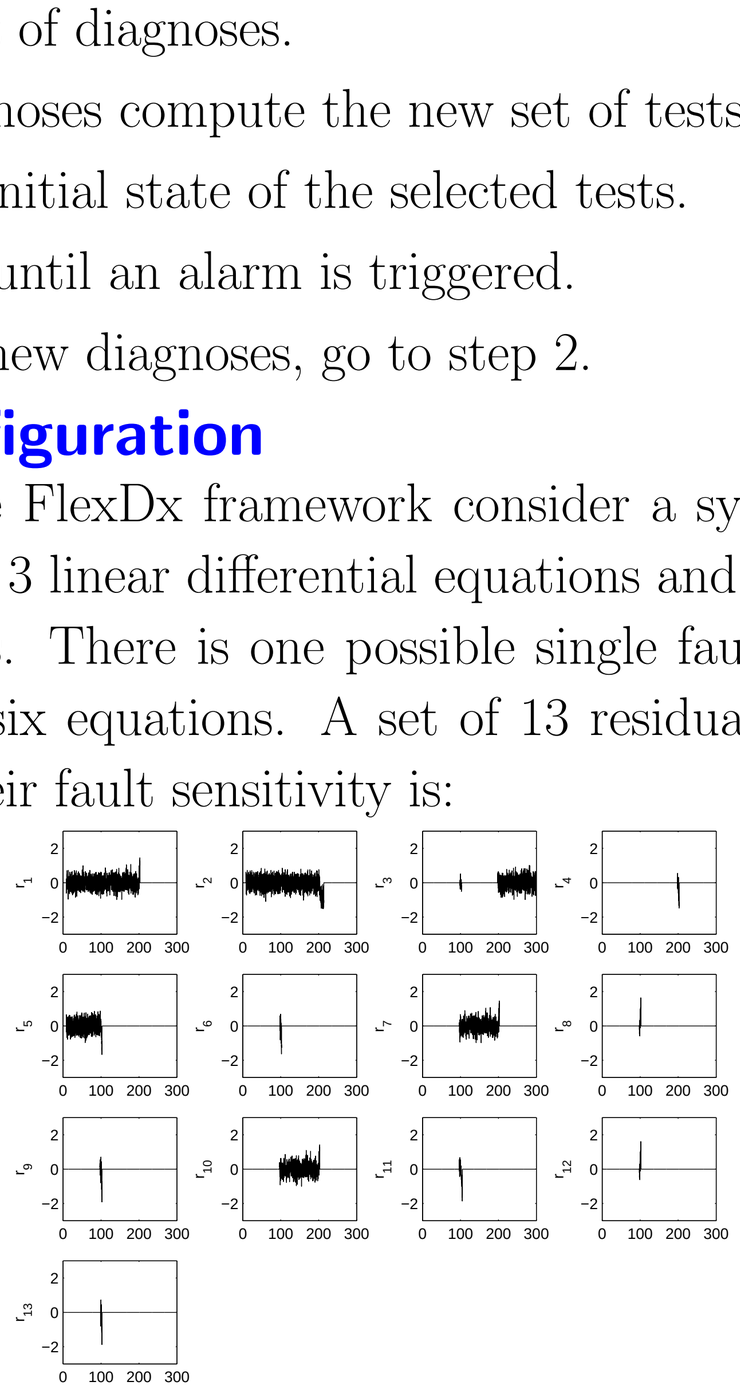
FlexDx incrementally refines the set of diagnoses according to the following procedure:

1. Initiate the set of diagnoses.
2. From the diagnoses compute the new set of tests.
3. Compute the initial state of the selected tests.
4. Run the tests until an alarm is triggered.
5. Compute the new diagnoses, go to step 2.

Test Reconfiguration

To illustrate the FlexDx framework consider a system modeled by 3 linear differential equations and 3 sensor equations. There is one possible single fault for each of the six equations. A set of 13 residuals are used and their fault sensitivity is:

	f_1	f_2	f_3	f_4	f_5	f_6
r_1				X	X	X
r_2		X	X		X	X
r_3		X	X	X		X
r_4		X	X	X	X	
r_5	X		X		X	X
r_6	X		X	X		X
r_7	X		X	X	X	
r_8	X	X			X	X
r_9	X	X		X		X
r_{10}	X	X		X	X	
r_{11}	X	X	X			X
r_{12}	X	X	X		X	
r_{13}	X	X	X	X		



To show how the diagnosis system is reconfigured during a fault transient, the fault f_1 at $t = 100$ was injected in a simulated scenario. The result is:

	t_{fault}	t_{alarm}	Minimal Diagnoses	Active Tests
1	0	102.6	NF	1, 2, 5
2	98.9	102.7	1, 3, 5, 6	1, 3, 10, 13
3	98.9	102.2	1, 3, 25, 26, 45, 46	1, 2, 6, 7, 8, 11, 12
4	98.9	102.3	1, 23, 25, 26, 35, 36, 45	1, 2, 6, 7, 9, 10, 11
5	98.9	102.6	1, 23, 26, 35, 36, 45	1, 2, 7, 9, 10, 11
6	98.9	105.2	1, 23, 26, 36, 45	1, 2, 7, 10, 11
7	100.6	–	1, 23, 26, 36, 245, 345, 456	1, 2, 7, 10

By comparing the number of multiplications and additions computed when running all tests at all times with the number computed by FlexDx, a 98% reduction is obtained for the simulated scenario.

Test Initialization

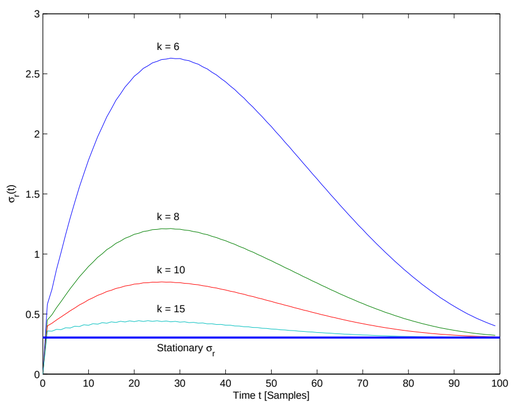
A time-window of samples of $w(t_{fault} - k + 1), \ldots, w(t_{fault})$ is used to find an initial state $x(t_{fault})$ for the following residual generator:

$$x(t+1) = Ax(t) + Bw(t)$$
$$r(t) = Cx(t) + Dw(t)$$

For a given window-length k, $x(t_{fault})$ is computed as the maximum likelihood solution to

$$x_0(t+1) = Ax_0(t) + Bw_0(t)$$
$$0 = Cx_0(t) + Dw_0(t)$$
$$w(t) = w_0(t) + Nv(t)$$

where $t = t_{fault} - k + 1, \ldots, t_{fault}$, $w_0(t)$ is the noise-free data (inputs and outputs) from the process model and $v(t)$ is Gaussian noise. The standard deviation of a residual can vary directly after initiation for different values of k as follows:



To get a maximum 10% increase of the false alarm probability the following number of observations is needed for the 13 tests: 38, 86, 65, 92, 23, 40, 52, 69, 41, 42, 113, 82, 108.

[1] F. Heintz, M. Krysander, J. Roll, and E. Frisk. FlexDx: A Reconfigurable Diagnosis Framework. In *19th International Workshop on Principles of Diagnosis (DX-08)*, Sydney, Australia, 2008.

[2] M. Krysander, F. Heintz, J. Roll, and E. Frisk. Dynamic Test Selection for Reconfigurable Diagnosis. In *47th IEEE Conf. on Decision and Control*, Cancun, Mexico, 2008.