Brainlike Sensing for Structural Testing

Adapted from *Concurrent Learning and Information Processing*
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Brainlike sensing systems offer major improvements in the complex testing of aircraft components. Aircraft structural testing often results in damage to expensive design prototypes. Damage results because all available strain gauge measurements cannot be monitored precisely during testing.

In a an aircraft manufacturing case study, advantages of Brainlike sensing during structural testing were demonstrated. Without relying on prior data analysis, Brainlike sensing identified an impending failure region in a heavily stressed tail section. The region was identified early enough so that damage would have been precluded if the system had been used.

The tail section used for the case study is illustrated in Figure 1. Hydraulic actuators attached to the tail section, located at the circles in the figure, applied loads to simulate in-flight maneuvers during several test trials. Loads were raised from low levels to high levels during each trial. Strain gauge readings at several time points during each trail were provided. Measurements were supplied in the form of one record per time point, with each record containing all gauge readings at that time point.

Brainlike sensing performed the following operations in real time:

- It learned the relationships among incoming gauge measurements during the first few measurement time points.
- It predicted measurement values for each gauge at each time point.
- It monitored measurement records for discrepancies between observed and predicted values at each time point.
- It updated learned relationships continuously to increase monitoring precision.
- It identified the region of developing damage prior to test article failure.

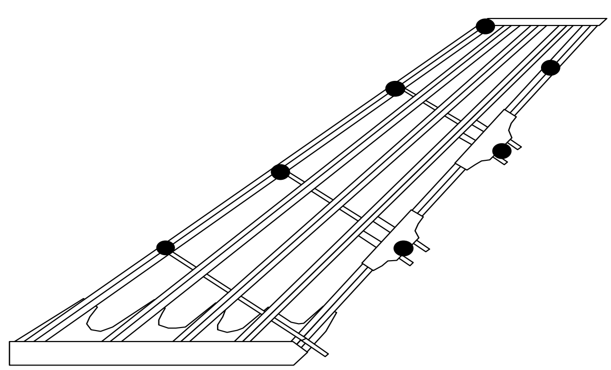

Figure 1. An Aerospace Structural Test Example

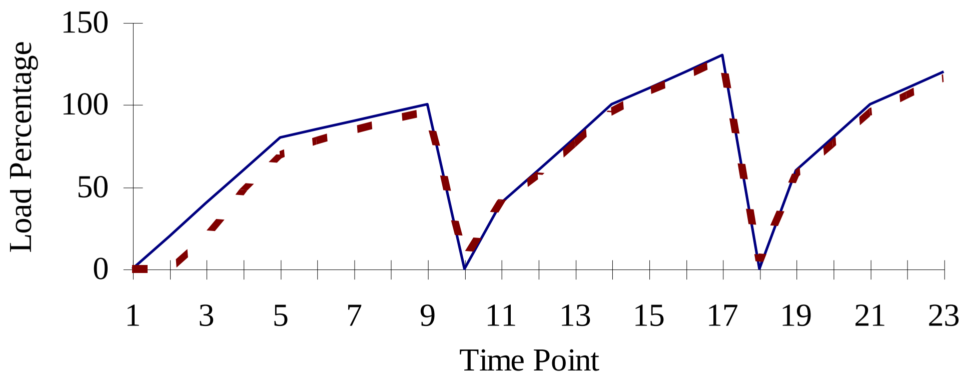

Figure 2. Load Versus Time During a Structural Test

A Brainlike sensing system received one set of 197 strain gauge measurements at each time point during three trials, during which the wing was loaded as shown in Figure 2. Learning without relying on previously gathered training data, the kernel accurately estimated each gauge value as a function of the other 196 values points and all 197 most recent values. In order to monitor at each time point, a deviance value was computed between each observed and estimated gauge value. If deviance values exceeded an alert criterion value, corresponding gauges were classified as deviant and their locations appeared in a deviant gauge location plot.

Figure 3 shows selected deviant gauge location plots that were prepared from Brainlike sensing values for the case study. Each plot displays deviant gauge locations according to the following color scheme. Each dark spot corresponds to a gauge that has just become deviant, while each light spot corresponds to a gauge that first became deviant prior to the current time point.

In operational settings using Brainlike sensing technology, test engineers will see displays like Figure 3 every few seconds. Using Brainlike sensing alerts, the will use such displays to scan a large number of data channels rapidly and identify regions of unusual activity. Looking at these displays will allow them to decide which gauges should be examined further and when to terminate a test.

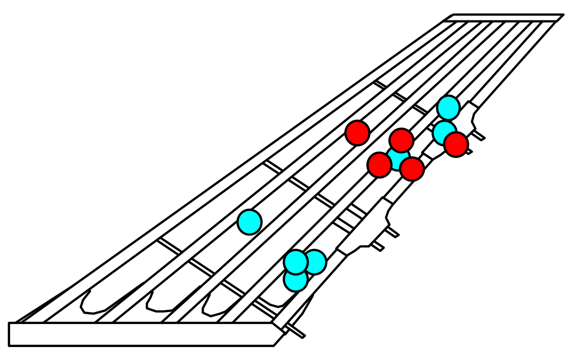

Figure 3. A Strain Gauge Monitoring Display

As part of the case study, test engineers were shown displays like Figure 3 from the middle of trial 1 onward. When they saw Figure 3 after viewing a series of uneventful displays, they said they would have examined deviant gauges in the figure before further continuing the structural test.

Figure 4 shows plotted observed and predicted values for one of the deviant gauges that the test engineers selected. The plot shows a developing departure between observed (solid) and predicted (dashed) gauge strain at the time point when Figure 3 was generated (point 19 on the plot). This was a clear early indicator of structural degradation, in that all test engineers participating in the case study said they would have discontinued the test at that point.

As it happened, test engineers did not have Brainlike sensing installed during actual the test. Since they had no indication that structural degradation was occurring, the test was continued well beyond time point 3. After a few more time points, the tail section visibly broke in the precise region that would have been identified by the system at time point 19.

This case study showed that Brainlike sensing adds monitoring value. Brainlike sensing systems can predict and monitor instrument readings without prior modeling, because they learn complex relationships *during* data entry. As a result, they offer simple and effective complements to first-principles, artificial intelligence and deep learning solutions for structural test monitoring.

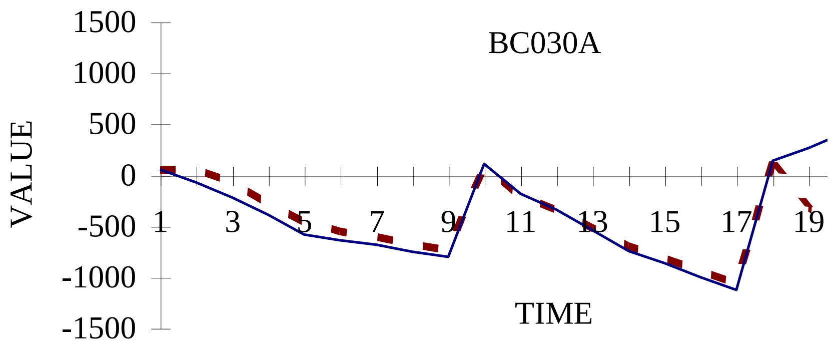

Figure 4. Observed and Predicted Values for a Selected Strain Gauge