



ARULE™ Reasoner

Part of the Sentinel Suite™ Family

Adaptive Remaining Useful Life Reasoner for PHM Applications

Features and Benefits

- Powerful algorithm to determine RUL and SoH
- Repeatabile and reliable results
- Fast and accurate health predictions
- Fault-to-failure progression (FFP) signature
- Degradation fault profile (DFP) signature
- Open architecture

General Description

Ridgetop's Adaptive Remaining Useful Life Estimator (ARULE) is a powerful reasoner to determine the remaining useful life (RUL) and state of health (SoH) of complex systems. Working from acquired sensor data, ARULE employs an advanced prediction method related to extended Kalman filtering (EKF) to produce new RUL and SoH estimates for each new sensor data point.

ARULE is versatile and can be used for determining electronic and mechanical fatigue damage. The reasoner calculates FFP signatures, accurate RUL (time-to-failure) estimates, and SoH estimates, which provide an early warning indicator for system maintenance personnel to schedule service to the system prior to catastrophic failure.

ARULE relies on diagnostic sensor data and a predefined model to produce an RUL estimate. It requires a sensor to "sense" data that are above a predefined "good-as-new" floor and below a "failed" ceiling. A new RUL estimate is produced based on changes to the model space; additionally, the new RUL estimate is used to produce a new SoH estimate.



Remaining useful life representation of a system with ARULE API deployed in a Sentinel IT™ application

ARULE uses intelligent algorithms that adapt the RUL according to changes in the level of stress to which the system is submitted. For cases where the level of stress is reduced, ARULE recognizes and accounts for evidence of healing in the data. This is shown by an increase in the RUL after acquisition of a certain amount of data that have changed the projection of the RUL estimate. When degradation resumes in the data, ARULE will also show degradation in its RUL and SoH estimates.

ARULE will recognize and apply a degradation fault profile (DFP) signature (derived from an anomaly detection filter), such as one that represents decreasing system power output.

ARULE operation, shown at right, consists of six steps: 1) sensor data are obtained; 2) a model from the model database is added; 3) data are conditioned and sent to the model predictor; where 4) a new model is generated; then 5) the new model is recorded/updated in the model database; and 6) results are sent to the user interface. The results provide information that supports condition-based maintenance (CBM).

Open Architecture

ARULE uses an open-architecture application programming interface (API) to define or use a model, accept input data, produce output RUL and SoH estimates, and return an adapted model. This API is available to support integration into on-board or off-board prognostics & health management (PHM) or CBM systems.

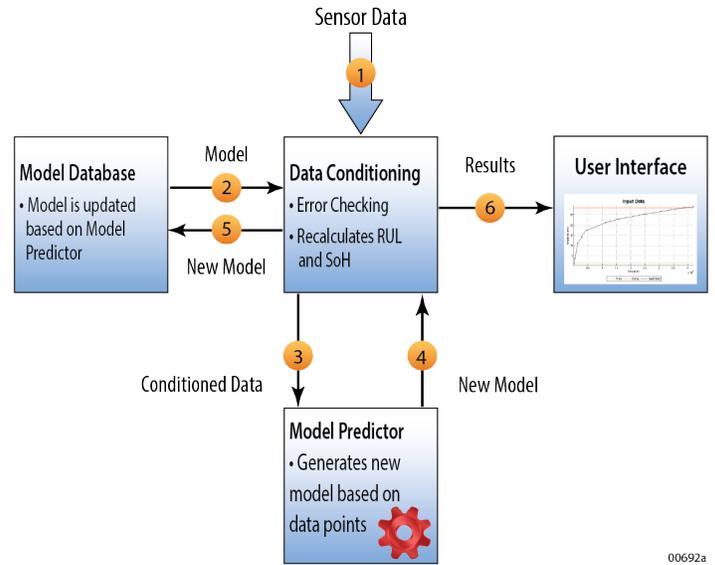
ARULE Summary

ARULE is an intrinsic component for Ridgetop's Sentinel Suite solutions, which encompass sensors, reasoners, and a graphical user interface (GUI). Sentinel Power™, Sentinel Motion™, and Sentinel IT™ implement ARULE as a reasoner to provide accurate prognostics of RUL and SoH for different applications.

About Ridgetop Group

Since its founding in 2000, Ridgetop has specialized in the development of advanced diagnostic and prognostic methods that are used to improve test coverage, improve reliability, reduce downtime, and

reduce the mean time to repair (MTTR) of critical systems. These cost-saving methods are incorporated in products that can be applied to electronic, power, and electromechanical systems found in aerospace, industrial, and automotive applications. Ridgetop also provides software-based development and monitoring tools supporting advanced CBM strategies.



ARULE reasoner operation

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ARULE Applications

- Power systems
- Battery management systems
- Actuator control systems
- Cable connection integrity



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