ARULE™ Prognostic Reasoner

Part of the Sentinel Suite™ Family

Adaptive Remaining Useful Life Estimator (ARULE) for PHM Applications
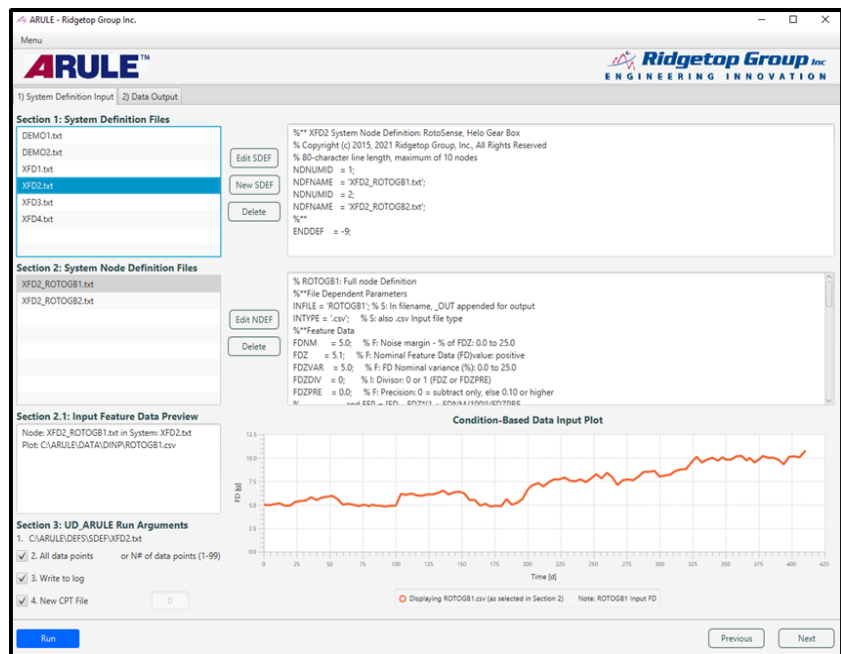
Features and Benefits

- Powerful prediction algorithms to determine SoH, RUL, and PH
- Fast, accurate, and repeatable prognostic health estimates
- Flexible system architecture to process condition-based Feature Data (FD) from multiple system nodes
- Generates reliable Fault-to-Failure Progression (FFP) signatures for each system node
- Has been proven to support prognostic applications for power supply systems, battery management systems, actuator controls, IT networks, and several other critical electro-mechanical systems and subsystems

General Description

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

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

Example of condition-based data from a helicopter gearbox application being analyzed with the ARULE Graphical User Interface (GUI)

ARULE relies on conditon-based sensor data to produce prognsotic estimates for RUL, SoH, and PH. It requires a sensor to report feature data that are above a predefined "good-as-new" floor and below a "failed" ceiling. A new RUL, SoH, and PH estimate is produced after each data point, and has been proven to have a fast convergance rate to the true time to system failure.

ARULE uses intelligent algorithms that dynamically adapt the RUL according to changes in the level of stress to which the system is subjected. 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 system degradation resumes, ARULE will also show degradation in its RUL, SoH, and PH estimates.

ARULE will recognize and apply a degradation progression signature (DPS) that has been derived from an anomaly detection filter, such as one that represents a degraded power supply system.

ARULE operation, shown at right, consists of five steps:

1) Condition-based sensor data are obtained
2) System definition and node definition files are created
3) ARULE keywords and parameters are specified
4) Input data files are conditioned and sent to the two-stage prognostic prediction engine to generate prognostic estimates for each data point
5) Data outputs are stored in .txt or .csv format and the results are displayed in the graphical user interface (GUI).

The results provide key information that support Prognostic Health Management (PHM), Condition-based Maintenance (CBM), and Integrated Vehicle Health Management (IVHM) applications.

Open Architecture

ARULE uses an open-architecture application programming interface (API) to create definition files, accept input data, and produce prognostic estimates for RUL, SoH, and PH. This API and Ridgetop engineers are available to support the integration into on-board or off-board systems and subsystems.

ARULE Summary

ARULE is an intrinsic component for Ridgetop's Sentinel Suite solutions, which encompass sensors, reasoners, and application software modules. Sentinel Power™, Sentinel Motion™, and Sentinel IT™ implement ARULE as a reasoner to provide accurate prognostic estimates for RUL, SoH, and PH for a wide variety of applications and use cases.

About Ridgetop Group

Ridgetop Group is an AS9100D and ISO:9001 certified organization located in Tucson, Arizona. Since its founding in 2000, Ridgetop has specialized in providing best in class CBM, PHM, and reliability engineering solutions to commercial and government organizations to increase safety, efficiency, and operational performance while also reducing maintenance and sustainment costs with the most innovative products and technology.

Our advanced diagnostic and prognostic methods are used to improve test coverage, improve reliability, reduce downtime, and reduce the mean time to repair (MTTR) of mission critical systems. These cost-saving methods are incorporated in products and services have been applied on numerous electromechanical systems and subsystems found in aerospace, defense, transportation, energy, medical, and industrial applications. Ridgetop also provides engineering design services for hardware, firmware, and software-based development programs related to the implementation of CBM, PHM, and IVHM strategies.
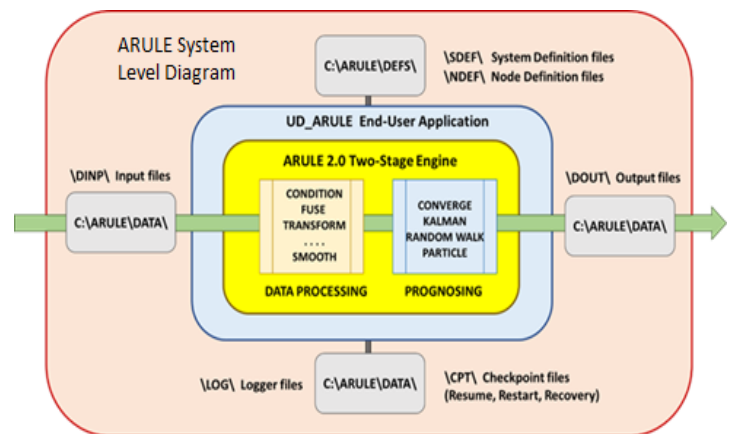
ARULE System Level Diagram

ARULE Applications

- Power supply systems
- Gearbox systems / transmissions
- Battery management systems
- Actuator control systems
- Cable connection integrity

Need modified or custom design? Contact Ridgetop at +1 520-742-3300 to discuss your ideal solution!

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