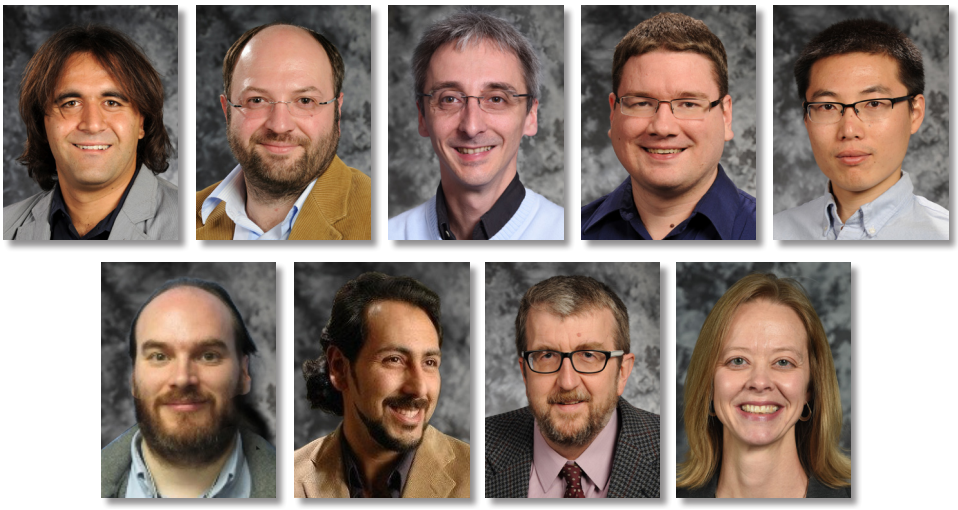
Risk Analysis Virtual Environment New Release: Version 2.0



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Risk-Informed Systems Analysis Pathway

The Risk Analysis and Virtual ENviroment (RAVEN) team recently released version 2.0 of the RAVEN software. This software is important to sustaining the existing fleet because it is designed to analyze safety, risk, uncertainty, maintenance, testing, and asset costs of current reactors to support proactive management approaches. This important update in the RAVEN software series represents an important step in its development, deployment, and consolidation of advanced capabilities for the probabilistic risk assessment (PRA), uncertainty quantification (UQ), data analysis, and machine learning (ML) communities, as observed in Figure 1.

The development of the RAVEN software has been supported by the Nuclear Energy Advanced Modeling and Simulation (NEAMS), the Light Water Reactor Sustainability (LWRS), and the Nuclear Energy Enabling Technologies Crosscutting Technology Development Integrated Energy System programs.

RAVEN provides a full and comprehensive set of capabilities to build analysis workflows based on state-of-the-art and advanced UQ, PRA, optimization, and ML techniques. The primary objectives of the software is to assist users to: (1) improve the performance of their physical design; (2) estimate the likelihood of undesired outcomes (risk analysis); (3) identify main parameters and events affecting the behavior of the model and their impact; and (4) construct analysis flows combining multiple physical models and analysis procedures.

RAVEN Version 2.0

RAVEN 2.0 features improved capabilities, specifically performance enhancements, and new user applications via new RAVEN plugins. The main additions and features include:

- **Performance and Parallelization** – Deployed a new system for optimizing the use of complex code. This new system starts up almost instantaneously.
- **Parallelization** – Replaced the "Parallel Python" system with the modern and powerful RAY library (https://docs.ray.io). RAY enables high performance computing massive parallelism reducing the parallel overhead resulting in improved scalability.
- **Optimization** – Developed a new optimization system with support for customizable interfaces, that enables: (1) a flexible code interface for ease in developing optimization algorithms (both internally and externally); and (2) support for probability distributions (e.g., risk-weighted and robust optimization). The new system allows for a much easier and quicker development of complex optimization approaches for designing and modifying complex systems.
- **Surrogate Models** – Deployed an interface with the Google supported library TensorFlow (https://www.tensorflow.org/). In addition, several improvements of the RAVEN synthetic time series generator have been developed (e.g., the generation of correlated multi signals with unbiased sampling for the synthetic time series generation).

- **Post Processing and Data Analysis** – RAVEN 2.0 has the following new post-processing capabilities:
  - *Risk Assessment*: Developed a new post-processor aimed to import/load/use minimal cut-sets generated by an external PRA code (e.g., SAPHIRE).
  - *Reliability Analysis*: Added the option to compute the bounding error of the limit surface (maximum error on the computed probability of failure).
  - *Economic Analysis*: Developed a "Pareto Frontier" algorithm for the identification of the points lying on a boundary in a cost-value space.

Plugins and Code Coupling

The RAVEN software has always been characterized by high "reusability" of the available algorithms and methods for deploying different use cases. RAVEN allows for the creation of plugins—software components that can be either imported by RAVEN as an additional toolbox or can use RAVEN as a calculation engine. In RAVEN 2.0, three new plugins have been released:

- **LOGOS**: Provides computational capabilities to optimize plant resources such as maintenance optimization and optimal component replacement schedule by using state-of-the-art discrete optimization methods.
- **SR2ML**: Provides sets of components and maintenance reliability models for quantification. These models can be used to determine an optimal system maintenance posture.
- **SRAW**: Provides sets of advanced workflows and methods to be applied to plant health and asset management. These methods focus on maintenance and replacement optimization and system reliability/unavailability.

In addition to the significant code enhancements, the documentation and training material has also been updated. The open source RAVEN 2.0 can be downloaded from: https://github.com/idaholab/raven/releases/tag/RAVENv2.0. https://raven.inl.gov: Version 2.0.

Figure 1. RAVEN capabilities.