

Notes on Generalized Information Theory with System of Systems Analysis Applications

Initial Presentation of Ideas

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System of systems analysis can benefit from fuzzy inference rules and interval analysis

1.0 Rule Development using Fuzzy Inference Systems (FIS)

Rules defined by subject matter experts provide an efficient interface between various systems. Sometimes systems might be sufficiently modeled independent of other systems; but their interdependency might be ambiguous.

Summary

- Subject matter experts define inference rules
- Ambiguous states can be accounted for
- A collection of FIS rules can be a quick and realistic modeling paradigm for systems characterized by uncertainty, e.g. nonlinearity, high-dimensionality and lack of knowledge about the boundary conditions.

2.0 Interval Analysis by means of Possibility Theory

Intervals can be useful to address situations where nonspecificity is predominant. Measurements can be observed and a distribution of intervals can be developed to progressively quantify more specific intervals.

Summary

- Develop a profile similar to a probability profile.
- Measure degree of confirmation of observed intervals relative to base observations.
- Regression analysis on intervals provides a bounding on data.

Detecting anomalous behavior and states of failure is essential for infrastructure analysis.

3.0 Anomaly Detection using Artificial Intelligence and FIS

Signals can be sampled, learned and compared against. When a “spike” in the difference between these signals occurs, an anomalous event has occurred. Fuzzy sets offer a benefit to this analysis by identifying the “strength” of the detection linguistically. An event can be categorized as “mild,” “serious,” or “severe” for example.

Summary

- Use Neural networks to learn complex response
- Subject matter experts define levels of anomaly identification.

4.0 Critical Scenario Identification

A system can be defined with a certain number of variables which take their values from a set $\{0, 1\}$. Subject matter experts define partial relations in the system. The set of partial relations is called a projection. A set of states is defined with various projections. These states can be failure of critical infrastructure components. And the projections can be infrastructure failure relationships within specific sectors. The question to be answered is, “What set of states (infrastructure component failures) results in system wide failure?”

Summary

- For a given projection, identify sets of states that are consistent with each partial relation.
- Measure the uncertainty of each projection along with its information content.
- Perform diagnostic analysis in the form of conditional uncertainties and information transmission.
- Use possibility values to represent partial relations.