DE LA RECHERCHE À L'INDUSTRIE

Scenario studies:

Optimization, uncertainty and beyond

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NUCLEAR SCENARIOS WITH COSI

COSI6

- COSI6 is the French reference code for scenario studies
- Developed at CEA for more than 25 years
- Discrete model in continuous time (discrete event simulation) a discrete fuel cycle
- Tracks 350 nuclides throughout the fuel cycle

COSI7

- COSI7 development beginning in fall 2017
- Main upgrades
  - New models for facilities for better industrial representativeness
    - Anticipation of fuel fabrication, homogenization of stocks and waste,
  - Improved user experience (real-time post-processing, etc.)
  - Expert UI (bottom-up) and decision-maker UI (top-down)
  - Compatibility with any depletion code
  - Improved performance

Fuel cycle optimization method

- Optimizing the fuel cycle:
  - Multiobjective optimization using meta-heuristics + surrogate models
  - Input parameters
    - Very high dimension, temporal scale problem with time-dependent input
    - Problem partially solved via smart encoding… but still a problem

What to optimize ?

- Looking for a strategy : exploration
  - Input: (too) many parameters + wide intervals for parameters
  - Output: usual, well-known criteria (cost, radiotoxicity, etc.)
- Improve a strategy : fine-tuning
  - Input: many parameters
  - Output: criteria difficult to implement: industrial feasibility, robustness, etc.

Results of an optimization study

- Results: minimal value of the output (or Pareto Front)
- The input associated with the minimal output is a by-product
  - Remark: the decision maker is interested in both input and output

Uncertainty propagation

- Uncertainty sources
  - Nuclear data (cross-sections, fission yields, etc.)
    - Well defined (covariance matrices)
    - But no so easy to take into account adequately (collapsed data + simplified models for scenarios)
    - Relatively low impact (at least on global, integrated outputs)
    - Convenient to study for physicists
  - Industrial data (burnup uncertainty, yields, rates, etc.)
    - Difficult to obtain data or consensus
    - Can be tricky to take into account (may require more detailed models or data framework)
    - Impact may be strong
  - Scenario hypotheses (fuel recycling strategy, prospective burnup value, uranium price, etc.)
    - Difficult to improve knowledge of scenario hypotheses
    - Impact is very strong
  - Policy changes
    - Difficult to improve knowledge of possible policy changes
    - Impact can be extremely strong (e.g. French Act on Energy Transition)

Class	Knowledge	Impact
Nuclear data	++	--
Industrial data	+	-
Scenario hypotheses	-	+
Policy changes	--	++

Uncertainty propagation

- Uncertainty propagation method
  - Surrogate models for fuel depletion (fast)
  - Modified physical models taking nuclear data into account
  - Formatting uncertainty data into “scenario friendly” data (covariance collapsing, etc.)
  - Monte-Carlo sampling

- Problem 1: Flat uncertainty propagation considers the decision-maker is not smart
  - Scenario is not readjusted to add new information when available
    - Example: one notices in 2050 than the scenario fails in 2100
    - Need to take action in 2050
  - Need to inject new data to find new goals to reach
  - Overall: flat uncertainty propagation seems to overestimate output uncertainty

- Problem 2: What is the output ?
  - Difference between input data for the code and input information for the scenario
  - Uncertainty propagation: what is the <u>code</u> input such that the <u>code</u> output complies with the <u>scenario</u> input information ?

NEXT STEPS

Identification of the next steps

- Improve the optimization process
  - Algorithms more efficient than the usual meta-heuristics? (Genetic A, Particle swarm, etc.)
  - Optimization under uncertainty
  - Inversion methods: use input-oriented algorithms instead of output-oriented algorithms

- Improve the uncertainty propagation
  - Scenarios are not a physical system: flat uncertainty propagation is not adapted
  - Need to take into account re-optimization / adjustment of scenario after perturbation

- Build robust scenarios
  - Robust scenario: remains relevant even after perturbation
  - Alternative proposition: possible to re-optimize after perturbation

Thank you for your attention

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