Numerical Experiments for Demand Driven Deployment Capabilities in Cyclus

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ABSTRACT

Nuclear Fuel Cycle (NFC) simulation scenarios are constrained objective functions. The objectives are systemic demands such as "1% power growth", while the constraints are availability of new nuclear technology. To adequately simulate a nuclear fuel cycle, NFC simulators must bring demand responsive deployment decisions into the dynamics of the simulation logic [1]. Thus, a NFC simulator should have the capability to deploy supporting fuel cycle facilities to meet a user-defined commodity demand. While automated power production deployment is common in most fuel cycle simulators, automated deployment of supportive fuel cycle facilities is non-existent. Instead, the user must detail the deployment timeline of all supporting facilities or have infinite capacity support facilities. This shortcoming exists in the fuel cycle simulator, Cyclus.

Cyclus is an agent-based nuclear fuel cycle simulation framework [2]. Each entity (i.e. Region, Institution, or Facility) in the fuel cycle is modeled as an agent. Institution agents are responsible for the deploying and decommissioning of facility agents and can represent a legal operating organization such as a utility, government, etc [2].

The Demand-Driven Cycamore Archetype project (NEUP-FY16-10512) aims to develop Cyclus's demand-driven deployment capabilities. This capability is developed in the form of a Cyclus Institution agent that deploys facilities to meet the front-end and back-end fuel cycle demands based on a user-defined commodity demand. Its goal is to meet supply for any commodity while minimizing oversupply. This demand-driven deployment capability is referred to as `d3ploy`.

At each time step, d3ploy predicts demand and supply of the following time step for each commodity. Based on the prediction, `d3ploy` deploys facilities to meet predicted demand. The user can select between four types of algorithms to govern demand and supply predictions: non-optimizing, time series forecasting, deterministic optimizing and machine learning.

We compared the prediction algorithms using numerical experiments that are in the form of fuel cycle scenarios in which the demand driving commodity, its demand curve and the combination of facilities in the scenario are varied. The types of fuel cycle scenarios studied include front-end facility deployment, back-end facility deployment, closed fuel cycle deployment and transition scenario deployment scenarios. We compared the results based on number of time steps where demand exceeds supply, residuals and χ^2 goodness of fit test. Based on these comparisons, it was determined that the non-optimizing methods were effective for predicting appropriate facility deployment for supplying the driving commodity. It was also found that the time series forecasting, deterministic and machine learning algorithms were effective for predicting appropriate facility deployment for supplying front-end and back-end commodities. The full paper will compare these prediction algorithms quantitatively, determine the advantages and disadvantages of each and provide recommendations for which algorithm is desirable for use in modeling transition scenarios.

REFERENCES

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