A deep-learning enabled approach to building robust and versatile computer-aided design tools

GHOSH D. (1), DATTA A. (1)
1 Cornell University, Ithaca, United States

Simulation-based product/process design tools critically depend on fast and accurate simulations. However, complex food process simulations are generally unwieldy for performing practical “what-if” scenarios for design and optimization, providing a major bottleneck in digital food manufacturing. Using convective drying of fruits as a popular process application, we show an approach to developing robust and user-friendly tools with vastly reduced computing resource needs for safety and quality simulations for a wide range of products and processes. Additionally, the tool includes a fast, efficient, and flexible algorithm for optimization of safety and quality within a wide range of parameter values.

The tool is built upon a complex multiphase and multicomponent porous media-based mechanistic model that shows good agreement with experimental data from a commercial dryer. However, for practical use, the tool needs to produce fast results. To this end, a surrogate of the mechanistic model is built by training a dynamic and memory-retaining neural network on the detailed spatiotemporal solution of temperature and moisture content, which is combined with safety and quality kinetics to predict a variety of safety and quality parameters of practical use. We have also explored two evolutionary optimization algorithms that can handle multi-objective problems with high-dimensional parameter space.
The surrogate model could make predictions in a negligible fraction of the time (4-6 seconds as opposed to ~4 hours) it takes to get the same results from the mechanistic model. Of the 40 test cases, 25% showed a RMSE value of less than 2^{o}C in temperature and 0.1 in db moisture content, while the median error was 5^{o}C in temperature and 0.2 in db moisture content when compared to the corresponding solution from the mechanistic model. The optimization algorithms showed remarkably fast convergence when compared to general exploratory methods of optimization.

The versatile digital tool (an app that can be run on a smartphone) with its robustness and quick predictive capability aides in practical product and process design through quick estimation and optimization of safety and quality in a drying process, reducing experimentation, shortening time-to-market, and providing avenues for novel changes that are much desired by industry.