FIPSE-6 Short Presentation 2a

Precision fermentation: Standing and upcoming challenges

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ABSTRACT

Precision fermentation relies on living catalysts that exhibit significant variations between batches. This complexity poses challenges in developing accurate control models. Control strategies, such as Model Predictive Control (MPC) are particularly prone to inaccuracies in models. A substantial challenge is developing models capable of delivering accurate predictions over extended time horizons, especially in the face of variable fermentation conditions. Hybrid models combining artificial neural networks and dynamic models present a potential solution However, their effectiveness is heavily reliant on a sizable training set. These hybrid models are still in the process of proving their efficacy, particularly in continuous fermentation scenarios that extend beyond 24 hours.

Reliable and frequent measurements often increase control performance, but the real-time acquisition of trustworthy measurements stands as a formidable challenge in precision fermentation. While real-time information on biomass and oxygen consumption is attainable, rates of sugar consumption and product formation pose significant challenges. Currently, accurate sugar consumption and product formation are primarily assessed using High-Performance Liquid Chromatography (HPLC). HPLC measurements can take up to 50 minutes or longer. Control algorithms like MPC need to optimize based on information that is nearly an hour old, which becomes obsolete in dynamic processes involving rapid exponential growth.

While faster data acquisition methods exist, they often sacrifice accuracy. Spectroscopy-based methods can provide high-frequency measurements, but they were not explicitly designed for the rapid changes in broth compositions common in microbial fermentation. These methods face challenges like increasing time variance, biased models, and saturation in dynamic microbial fermentation environments. Finding a balance between frequent and accurate measurements remains a critical consideration in advancing feedback information for precision fermentation.

Lastly, state estimators such as extended Kalman filters and moving horizon estimators, are soft-sensors that integrate multiple feedback measurements, models, *a priori* process statistics, and even optimization-based algorithms to obtain better process feedback information. However, due to the rapidly changing conditions, process uncertainty, and complex noise, estimators can become highly inaccurate, especially when relying on poor models. Creating effective state estimators that can provide useful feedback control information is still a challenge in precision fermentation but may significantly increase control performance once resolved.

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