Image-based feature extraction for EPS monitoring on WWTP bioreactors

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With the emergence of Industry 4.0, a wide variety of data collectors became available. Among them, image-based systems are becoming more and more popular and easily accessible (Reis, 2014). Therefore, there is an opportunity for integrating images for process monitoring and supervision activities. In the present work, we consider a Wastewater Treatment Plant (WWTP) composed by several bio-reactors where a quality parameter should be estimated and monitored: Extracellular Polymer Substances (EPS). These substances are responsible for linking the cells and forming aggregates or flocks (Liu & Fang 2003). The analysis of EPS-related particle is currently done offline through microscopic observation by trained specialists, introducing a significant variation in microscopic image evaluation by different specialists, and limiting the consistency among different images.

In this context, the goal of the present work is to develop and deploy a fast and reliable methodology that estimates the level of EPS while simultaneously extracting relevant features for identifying periods of good and deviating performance in the bioreactors. The inputs for the algorithm are Indian ink-dyed microscopic images of samples taken from the bioreactors.

The proposed scheme combines digital image processing techniques and chemometrics tools in an algorithm that can achieve the proposed goal. This procedure starts with color intensity transformation to grayscale, followed by a specific image segmentation step (Gonzalez 2009), where all objects are detected and isolated, from which EPS can then be estimated. Object features and their distributions are summarized in a set of descriptors, which were treated by multivariate statistical methodologies for identifying good and bad images and operating periods.

The proposed procedure for EPS estimation achieved a $R^2 = 0.95$ with a RMSE = 0.98 %. The methodology with this estimation accuracy was applied to an image database and used to monitor both the intra-sample and between-sample variability, using X-bar and R Shewhart control charts (Montgomery 2013). In this way, process variability and sample consistency were simultaneously estimated and monitored. Furthermore, the proposed methodology was able to detect bad quality images and features that discriminate between good and deviating periods in the operation of the reactors.

References

Montgomery, D. C. (2013), *Introduction to Statistical Quality Control*, 7th ed, John Wiley & Sons, Inc.

Reis, M. S. (2014), *Multivariate image analysis*, in '*Mathematical and Statistical Methods in Food Science and Technology*', John Wiley & Sons, Ltd., chapter 12, pp. 201–218

Gonzalez, R. C., Woods, R. E. & Eddins, S. L. (2009), *Digital Image Processing Using Matlab*, 2nd ed, Gatesmark Publishing.

Liu, Y. & Fang, H. H. P. (2003), '*Influences of Extracellular Polymeric Substances (EPS) on Flocculation, Settling, and Dewatering of Activated Sludge*', Critical Reviews in Environmental Science and Technology, 33(3), 237-273