Modelling of Aerobic Granulation using Neural Networks and Fuzzy Logic

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Introduction

Aerobic Granulation (AG) is an efficient wastewater treatment technology, but the underlying processes are complicated. Many factors play important roles for the successful operation of the reactor and the determination of the predominant bacteria: reactor design and operation, type of influent wastewater, and type of seed sludge. Aerobic granulation is still being investigated, and at this stage, simulating the process will provide a great tool for fast testing and prediction of performance.

Conventional Modelling

- Mathematical modelling of AG is compartmentalized. Different compartments are settling, particle selection, bio-kinetics, granule physical variation, and mass transfer
- These compartments are either empirical equations or complicated differential equations
- They require calibration and verification for each scenario
- There are several assumptions made to simplify the mathematics
- Bio-kinetics are based on activated sludge models, while AG is a much different and a far more complicated process

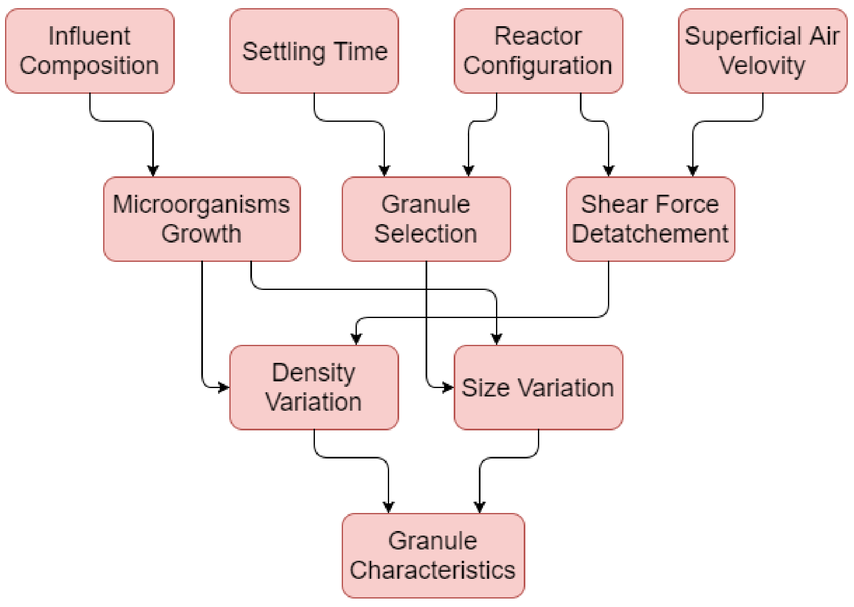

Figure 1. Process breakdown and dependencies in aerobic granulation

Neural Networks and Fuzzy Logic

- Neural Networks process data in the same way as the human brain. They provide accurate nonlinear relationships of input-output pairs of data without developing a mathematical function, i.e. learning from data.
- Fuzzy logic is a method that favors significance of information over precision. This is achieved by expanding the binary state of data to a range of [0, 1] via membership functions. This method greatly simplifies complicated mathematical problems.
- Coupling neural networks and fuzzy logic combines the simplicity with adaptability and learning ability, creating a powerful modelling tool for AG.

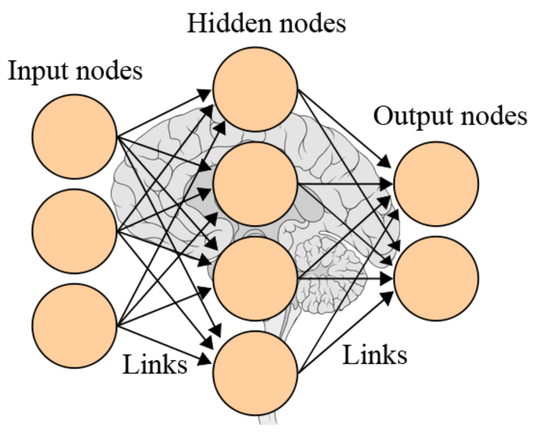

Figure 2. Neural Networks

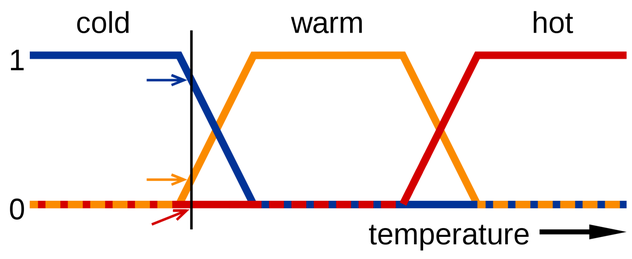

Figure 3. Fuzzy Logic membership functions

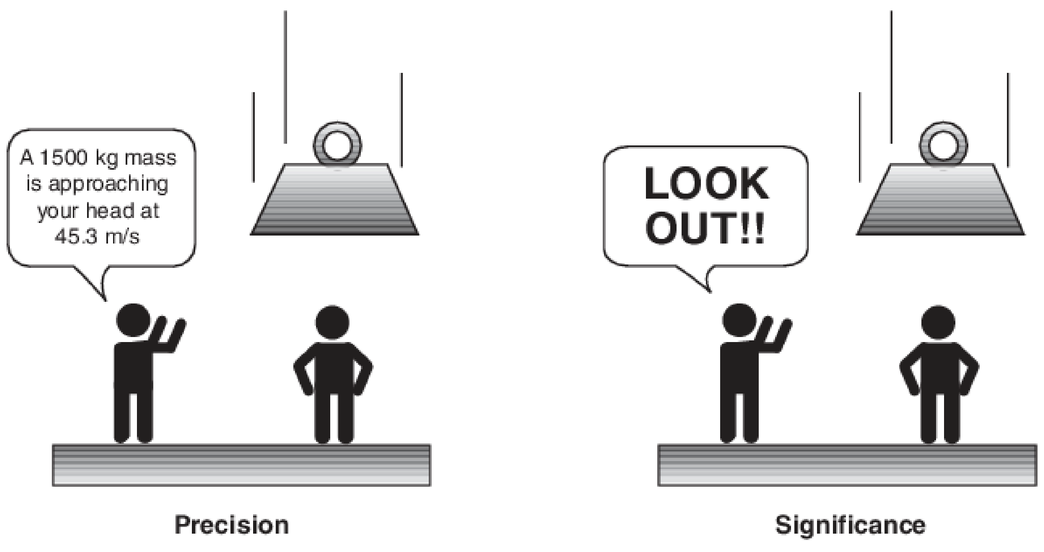

Figure 4. Precision vs Significance

Research Plan

- Data availability is the core of artificial intelligence modelling. Laboratory data collection from a 5 L aerobic granulation reactor will be done for COD, N, P, VSS, TSS, DO, pH, SVI, particle size, SVI and operational conditions. In addition to the data available from the literature.
- The data set should be non repetitive, which means that there must be different scenarios in order for the model to learn and be representative. Feed COD will be varied between 500 and 2000 mg/l (OLR 1.75 to 7 kgCOD/m^3.d) with C:N:P ratio of 100:5:1.
- A neural network model, a kinetic model (mathematical), and a neural fuzzy model will be developed for the same data set. Their performance will be compared in terms of accuracy of prediction, complexity, and computational power requirement.

Expected Outcomes

- Two artificial intelligence models that can be readily used to simulate aerobic granulation
- A kinetic model that can be used to study biological processes of AG
- A mass transfer model that describes the movement of the wastewater components within the granules

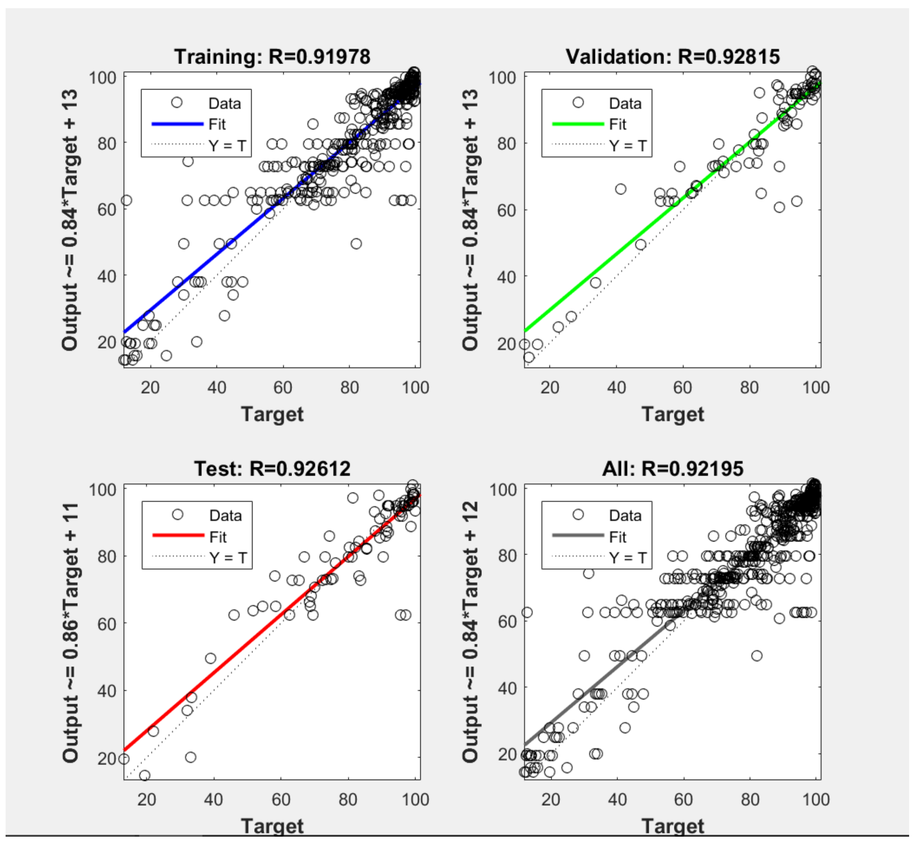

Figure 5.Resuts of a Neural Networks model for COD removal

Advantages and Applications

Modelling of AG is gaining attention for its significant impact on the research advancement. Using artificial intelligence has strong advantages and widens the scope of applications of AG modelling, as follows:

- Avoids the complication of mathematical modeling
- Avoids making unrealistic assumptions
- Provides adaptability and learning ability
- Provides faster simulation time
- Can be used in the plant design stage
- Can be used for real-time decision making when coupled with online sensors
- Can be used towards full automation of treatment plants on remote areas

References

- Jang, J. S. R. (1993). ANFIS: adaptive-network-based fuzzy inference system. *Systems, Man and Cybernetics, IEEE Transactions on*, *23*(3), 665-685.
- Gujer, W., Henze, M., Mino, T., & Van Loosdrecht, M. (1999). Activated sludge model no. 3. *Water Science and Technology*, *39*(1), 183-193.
- Ni, B., & Yu, H., (2010), “Mathematical modeling of aerobic granular sludge: A review”, *Biotechnology Advances*, 28(6), 895-909
- Su, K., Ni, B., & Yu, H., (2013), “ Modeling and optimization of granulation process of activated sludge in sequencing batch reactors”, *Biotechnology and Bioengineering*, 110(5), 1312-1322.
- Chen, Yao, Wenju Jiang, David Tee Liang, and Joo Hwa Tay. 2008. “Biodegradation and Kinetics of Aerobic Granules under High Organic Loading Rates in Sequencing Batch Reactor.” *Applied Microbiology and Biotechnology, 79*(2): 301–8.

Acknowledgements

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