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Real-Time Substrate Feed Optimization of Anaerobic Co-Digestion Plants

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Bibliography

- C.-A. Aceves-Lara, E. Latrille, and J.-P. Steyer. Optimal control of hydrogen production in a continuous anaerobic fermentation bioreactor. *Int J Hydrogen Energy*, 35(19):10710–10718, Oct. 2010. doi: 10.1016/j.ijhydene.2010.02.110.
- V. Adetola and M. Guay. Integration of real-time optimization and model predictive control. *Journal of Process Control*, 20(2):125–133, 2010.
- Agentschap NL. www.b-i-o.nl, 2013.
- E. Aguilar-Garnica, D. Dochain, V. Alcaraz-González, A. K. Dramé, and V. González-Álvarez. COD and VFA’s control in a two-phase anaerobic digestion process. *Computer Applications in Biotechnology*, 10(1):67–72, June 2007. doi: 10.3182/20070604-3-MX-2914.00013.
- E. Aguilar-Garnica, D. Dochain, V. Alcaraz-González, and V. González-Álvarez. A multivariable control scheme in a two-stage anaerobic digestion system described by partial differential equations. *Journal of Process Control*, 19(8):1324–1332, Sept. 2009. doi: 10.1016/j.jprocont.2009.04.003.
- B. K. Ahring, M. Sandberg, and I. Angelidaki. Volatile fatty acids as indicators of process imbalance in anaerobic digestors. *Applied Microbiology and Biotechnology*, 43(3):559–565, July 1995. doi: 10.1007/BF00218466.
- E. Alba and C. Cotta. Evolutionary Algorithms. In S. Olariu and A. Y. Zomaya, editors, *Handbook of Bioinspired Algorithms and Applications*, chapter 1, pages 3–19. Taylor & Francis, 2006.
- V. Alcaraz-González and V. González-Álvarez. Robust Nonlinear Observers for Bioprocesses: Application to Wastewater Treatment. *Lecture Notes in Control and Information Sciences - Selected Topics in Dynamics and Control of Chemical and Biological Processes*, 361:119–164, 2007.
- V. Alcaraz-González, A. Maloum, J. Harmand, A. Rapaport, J. Steyer, V. González-Álvarez, and C. Pelayo-Ortiz. Robust interval-based SISO and SIMO regulation for a class of highly uncertain bioreactors: Application to the anaerobic digestion. In *Proceedings of the 39th IEEE Conference on Decision and Control (Cat. No.00CH37187)*, volume 5, pages 4532–4537. IEEE, 2000. doi: 10.1109/CDC.2001.914625.
- V. Alcaraz-González, J. Harmand, A. Rapaport, J. Steyer, V. González-Álvarez, and C. Pelayo-Ortiz. Robust interval-based SISO regulation under maximum uncertainty conditions in an anaerobic digester. In *Proceeding of the 2001 IEEE International Symposium on Intelligent Control (ISIC ’01)*, pages 240–245. IEEE, 2001. doi: 10.1109/ISIC.2001.971515.
- V. Alcaraz-González, J. Harmand, A. Rapaport, J. P. Steyer, V. González-Álvarez, and C. Pelayo-Ortiz. Robust interval-based regulation for anaerobic digestion processes. *Water Science and Technology*, 52(1-2):449–56, Jan. 2005.

- V. Alcaraz-González, R. H. López-Bañuelos, J.-P. Steyer, H. O. Méndez-Acosta, V. González-Álvarez, and C. Pelayo-Ortiz. Interval-Based Diagnosis of Biological Systems - a Powerful Tool for Highly Uncertain Anaerobic Digestion Processes. *CLEAN - Soil, Air, Water*, 40(9):941–949, Sept. 2012. doi: 10.1002/clen.201100721.
- A. Alessandri, M. Baglietto, and G. Battistelli. Moving-horizon state estimation for nonlinear discrete-time systems: New stability results and approximation schemes. *Automatica*, 44(7):1753–1765, July 2008. doi: 10.1016/j.automatica.2007.11.020.
- A. Alessandri, M. Baglietto, G. Battistelli, and V. Zavala. Advances in moving horizon estimation for nonlinear systems. In *49th IEEE Conference on Decision and Control (CDC)*, pages 5681–5688, Atlanta, Dec. 2010. IEEE. doi: 10.1109/CDC.2010.5718126.
- A. Alessandri, M. Baglietto, G. Battistelli, and M. Gaggero. Moving-horizon state estimation for nonlinear systems using neural networks. *IEEE Trans Neural Netw*, 22(5):768–80, May 2011. doi: 10.1109/TNN.2011.2116803.
- J. Alferes and I. Irizar. Combination of extremum-seeking algorithms with effective hydraulic handling of equalization tanks to control anaerobic digesters. *Water Sci Technol*, 61(11):2825–34, Jan. 2010. doi: 10.2166/wst.2010.093.
- J. Alferes, J. L. García-Heras, E. Roca, C. García, and I. Irizar. Integration of equalisation tanks within control strategies for anaerobic reactors. Validation based on ADM1 simulations. *Water Sci Technol*, 57(5):747–52, Jan. 2008. doi: 10.2166/wst.2008.104.
- J. Alvarez-Ramirez, R. Femat, O. Monroy, and F. Cuervo. An adaptive control strategy for anaerobic digester. In *Proceeding of the 1996 IEEE International Conference on Control Applications*, pages 1019–1024. IEEE, 1996. doi: 10.1109/CCA.1996.559055.
- J. Alvarez-Ramirez, M. Meraz, O. Monroy, and A. Velasco. Feedback control design for an anaerobic digestion process. *J Chem Technol Biot*, 77(6):725–734, June 2002. doi: 10.1002/jctb.609.
- R. M. B. Alves, C. A. O. Nascimento, E. C. Biscaia, L. A. Alvarez, and D. Odloak. Robust integration of real time optimization with linear model predictive control. *Computers & Chemical Engineering*, 34(12):1937–1944, 2010.
- J. F. Andrews. A Dynamic Model of the Anaerobic Digestion Process. In *Proceedings of the 23rd Industrial Waste Conference*, pages 285–310, 1968.
- J. F. Andrews. Dynamic models and control strategies for wastewater treatment processes. *Water Res*, 8(5):261–289, May 1974. doi: 10.1016/0043-1354(74)90090-6.
- I. Angelidaki, M. Alves, D. Bolzonella, L. Borzacconi, J. L. Campos, a. J. Guwy, S. Kalyuzhnyi, P. Jenicek, and J. B. van Lier. Defining the biomethane potential (BMP) of solid organic wastes and energy crops: a proposed protocol for batch assays. *Water Sci Technol*, 59(5):927–34, Jan. 2009. doi: 10.2166/wst.2009.040.
- F. Angulo, G. Olivar, and A. Rincon. Control of an anaerobic upflow fixed bed bioreactor. In *2007 Mediterranean Conference on Control & Automation*, pages 1–6, Athens, June 2007. IEEE. doi: 10.1109/MED.2007.4433758.
- R. Antonelli, J. Harmand, J. Steyer, and A. Astolfi. Output feedback regulation of an anaerobic digestion process. In *Proceedings of the 2002 American Control Conference (IEEE Cat. No.CH37301)*, volume 5, pages 4062–4067. American Automatic Control Council, 2002. doi: 10.1109/ACC.2002.1024565.

- R. Antonelli, J. Harmand, J.-P. Steyer, and A. Astolfi. Set-point regulation of an anaerobic digestion process with bounded output feedback. *IEEE T Contr Syst T*, 11(4):495–504, July 2003. doi: 10.1109/TCST.2003.813376.
- L. Appels, J. Baeyens, J. Degreève, and R. Dewil. Principles and potential of the anaerobic digestion of waste-activated sludge. *Progress in Energy and Combustion Science*, 34(6):755–781, Dec. 2008. doi: 10.1016/j.pecs.2008.06.002.
- S. Astals, M. Esteban-Gutiérrez, T. Fernández-Arévalo, E. Aymerich, J. L. García-Heras, and J. Mata-Alvarez. Anaerobic digestion of seven different sewage sludges: A biodegradability and modelling study. *Water research*, 47(16):6033–43, Oct. 2013. doi: 10.1016/j.watres.2013.07.019.
- P. Axaopoulos, P. Panagakis, A. Tsavdaris, and D. Georgakakis. Simulation and experimental performance of a solar-heated anaerobic digester. *Solar Energy*, 70(2):155–164, Jan. 2001. doi: 10.1016/S0038-092X(00)00130-4.
- M. W. Barnett and J. F. Andrews. Expert System for Anaerobic Digestion Process Operation. *Journal of Environmental Engineering*, 118(6):949–963, Nov. 1992. doi: 10.1061/(ASCE)0733-9372(1992)118:6(949).
- G. Bastin and D. Dochain. *On-line Estimation and Adaptive Control of Bioreactors (Process Measurement and Control, 1)*. Elsevier Science, Amsterdam, 1990.
- D. J. Batstone and J.-P. Steyer. Use of modelling to evaluate best control practice for winery-type wastewaters. *Water Sci Technol*, 56(2):147, July 2007. doi: 10.2166/wst.2007.483.
- D. J. Batstone, J. Keller, I. Angelidaki, S. V. Kalyuzhnyi, S. G. Pavlostathis, A. Rozzi, W. T. M. Sanders, H. Siegrist, and V. a. Vavilin. The IWA Anaerobic Digestion Model No 1 (ADM1). *Water Sci Technol*, 45(10):65–73, Jan. 2002a.
- D. J. Batstone, J. Keller, I. Angelidaki, S. V. Kalyuzhnyi, S. G. Pavlostathis, A. Rozzi, W. T. M. Sanders, H. Siegrist, and V. A. Vavilin. *Anaerobic Digestion Model No.1 (ADM1)*. IWA Publishing, 1st edition, 2002b.
- D. J. Batstone, K. V. Gernaey, and J. P. Steyer. Instrumentation and Control in Anaerobic Digestion. In *2nd IWA Leading-Edge Conference on Water and Wastewater Treatment Technologie*, pages 173–182, London, 2004. IWA Publishing.
- D. J. Batstone, S. Tait, and D. Starrenburg. Estimation of hydrolysis parameters in full-scale anerobic digesters. *Biotechnol Bioeng*, 102(5):1513–20, Apr. 2009. doi: 10.1002/bit.22163.
- A. Bemporad and D. Muñoz de la Peña. Multiobjective model predictive control. *Automatica*, 45(12):2823–2830, Dec. 2009. doi: 10.1016/j.automatica.2009.09.032.
- A. Benhalla, M. Houssou, and M. Charif. Linearization of the full activated sludge model No 1 for interaction analysis. *Bioproc Biosyst Eng*, 33(6):759–71, Aug. 2010. doi: 10.1007/s00449-009-0404-z.
- J. M. Berg, J. L. Tymoczko, and L. Stryer. *Stryer Biochemie (German Edition)*. Springer Spektrum, 6th edition, 2007.
- M. Berglund and P. I. Börjesson. Assessment of energy performance in the life-cycle of biogas production. *Biomass and Bioenergy*, 30(3):254–266, Mar. 2006. doi: 10.1016/j.biombioe.2005.11.011.

- O. Bernard, Z. Hadj-Sadok, and D. Dochain. Software sensors to monitor the dynamics of microbial communities: application to anaerobic digestion. *Acta biotheoretica*, 48 (3-4):197–205, Dec. 2000.
- O. Bernard, Z. Hadj-Sadok, D. Dochain, A. Genovesi, and J. P. Steyer. Dynamical model development and parameter identification for an anaerobic wastewater treatment process. *Biotechnol Bioeng*, 75(4):424–38, Nov. 2001a.
- O. Bernard, M. Polit, Z. Hadj-Sadok, M. Pengov, D. Dochain, M. Estaben, and P. Labat. Advanced monitoring and control of anaerobic wastewater treatment plants: software sensors and controllers for an anaerobic digester. *Water Sci Technol*, 43(7):175–82, Jan. 2001b.
- S. Besgen. *Energie- und Stoffumsetzung in Biogasanlagen*. Dissertation, Rheinische Friedrich-Wilhelm-Universität Bonn, 2005.
- N. Beume, B. Naujoks, and M. Emmerich. SMS-EMOA: Multiobjective selection based on dominated hypervolume. *European Journal of Operational Research*, 181(3): 1653–1669, Sept. 2007. doi: 10.1016/j.ejor.2006.08.008.
- N. Beume, B. Naujoks, and G. Rudolph. SMS-EMOA - Effektive evolutionäre Mehrziel-optimierung (SMS-EMOA - Effective Evolutionary Multiobjective Optimization). *at - Automatisierungstechnik*, 56(7):357–364, July 2008. doi: 10.1524/auto.2008.0715.
- H.-G. Beyer and B. Sendhoff. Evolution Strategies for Robust Optimization. In *2006 IEEE International Conference on Evolutionary Computation*, pages 1346–1353, Vancouver, BC, 2006. IEEE. doi: 10.1109/CEC.2006.1688465.
- L. T. Biegler. Solution of dynamic optimization problems by successive quadratic programming and orthogonal collocation. 1984.
- W. Bischofsberger, N. Dichtl, K.-H. R. Carl, and F. Seyfried. *Anaerobtechnik*. Springer-Verlag, Berlin/Heidelberg, 2005. doi: 10.1007/b137857.
- L. Björnsson, M. Murto, and B. Mattiasson. Evaluation of parameters for monitoring an anaerobic co-digestion process. *Appl Microbiol Biot*, 54(6):844–9, Dec. 2000.
- BMU. Gesetz für den Vorrang Erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG), 2009.
- BMU. Renewable Energy Sources Act - EEG, 2012a.
- BMU. *Messmethodensammlung Biogas*. DBFZ, Leipzig, 1st edition, 2012b.
- K. Boe. *Online monitoring and control of the biogas process*. Ph.d., Technical University of Denmark, 2006.
- K. Boe and I. Angelidaki. Pilot-scale application of an online VFA sensor for monitoring and control of a manure digester. *Water Sci Technol*, 66(11):2496–503, Jan. 2012. doi: 10.2166/wst.2012.498.
- K. Boe, J.-P. Steyer, and I. Angelidaki. Monitoring and control of the biogas process based on propionate concentration using online VFA measurement. *Water Sci Technol*, 57(5):661–6, Jan. 2008. doi: 10.2166/wst.2008.046.
- K. Boe, D. J. Batstone, J.-P. Steyer, and I. Angelidaki. State indicators for monitoring the anaerobic digestion process. *Water research*, 44(20):5973–80, Dec. 2010. doi: 10.1016/j.watres.2010.07.043.

- A. Boscolo, C. Mangiavacchi, F. Drius, F. Rongione, P. Pavan, and F. Cecchi. Fuzzy control of an anaerobic digester for the treatment of the organic fraction of municipal solid waste (MSW). *Water Sci Technol*, 27(2):57–68, Mar. 1993.
- S. Boyd and L. Vandenberghe. *Convex optimization*. Cambridge University Press, Cambridge, 2004.
- L. Breiman. Random forests. *Machine learning*, 45(1):5–32, 2001. doi: 10.1023/A:1010933404324.
- R. S. Brito, H. Pinheiro, F. Ferreira, J. S. Matos, and N. Lourenço. In situ UV-Vis spectroscopy to estimate COD and TSS in wastewater drainage systems. *Urban Water Journal*, pages 1–13, June 2013. doi: 10.1080/1573062X.2013.783087.
- R. Brun, P. Reichert, and H. R. Künsch. Practical identifiability analysis of large environmental simulation models. *Water Resources Research*, 37(4):1015–1030, Apr. 2001. doi: 10.1029/2000WR900350.
- J. Busch, P. Kühn, and J. Schlöder. State estimation for large-scale wastewater treatment plants. *Advanced Control of Chemical Processes*, 7(1):596–601, July 2009. doi: 10.3182/20090712-4-TR-2008.00096.
- J. Busch, D. Elixmann, P. Kühn, C. Gerken, J. P. Schlöder, H. G. Bock, and W. Marquardt. State estimation for large-scale wastewater treatment plants. *Water research*, 47(13):4774–87, Sept. 2013. doi: 10.1016/j.watres.2013.04.007.
- S. Carlos-Hernandez, J. F. Beteau, and E. N. Sanchez. Intelligent control strategy for an anaerobic fluidized bed reactor. In P. Michel, editor, *Computer Applications in Biotechnology*, volume 1, pages 73–78, Cancun, Mexico, June 2007. doi: 10.3182/20070604-3-MX-2914.00014.
- S. Carlos-Hernandez, E. Sanchez, and J. Béteau. Fuzzy observers for anaerobic WWTP: Development and implementation. *Control Engineering Practice*, 17(6):690–702, June 2009. doi: 10.1016/j.conengprac.2008.11.008.
- S. Carlos-Hernandez, E. Sanchez, and J. Beteau. Fuzzy Control Strategy for an Anaerobic Wastewater Treatment Process. *Chem Biochem Eng Q*, 24(2):235–245, 2010a.
- S. Carlos-Hernandez, E. Sanchez, and J. Bueno. Neurofuzzy Control Strategy for an Abattoir Wastewater Treatment Process. In J. R. Banga, P. Bogaerts, J. V. Impe, D. Dochain, and I. Smets, editors, *11th International Symposium on Computer Applications in Biotechnology*, number Cab, pages 84–89, Leuven, Belgium, 2010b.
- E. Carrasco. Rule-based diagnosis and supervision of a pilot-scale wastewater treatment plant using fuzzy logic techniques. *Expert Systems with Applications*, 22(1):11–20, Jan. 2002. doi: 10.1016/S0957-4174(01)00045-8.
- M. Castellano, G. Ruiz-Filippi, W. González, E. Roca, and J. Lema. Selection of variables using factorial discriminant analysis for the state identification of an anaerobic UASB-UAF hybrid pilot plant, fed with winery effluents. *Water Sci Technol*, 56(2):139, July 2007. doi: 10.2166/wst.2007.482.
- Centraal Bureau voor de Statistiek. Hernieuwbare energie in Nederland 2012. Technical report, Centraal Bureau voor de Statistiek, Den Haag/Heerlen, 2013.
- A. Chamroo, I. Simeonov, C. Vasseur, and N. Christov. On the Piecewise Continuous Control of Methane Fermentation Processes. *Studies in Informatics and Control*, 17(2):181–188, 2008.

- J. Che and J. Wang. Short-term electricity prices forecasting based on support vector regression and Auto-regressive integrated moving average modeling. *Energy Conversion and Management*, 51(10):1911–1917, 2010.
- Y. Chen, J. J. Cheng, and K. S. Creamer. Inhibition of anaerobic digestion process: a review. *Bioresource technology*, 99(10):4044–64, July 2008. doi: 10.1016/j.biortech.2007.01.057.
- F. Cherubini and A. H. Strømman. Life cycle assessment of bioenergy systems: state of the art and future challenges. *Bioresource technology*, 102(2):437–51, Jan. 2011. doi: 10.1016/j.biortech.2010.08.010.
- H.-H. Chou, J.-S. Huang, S.-K. Chen, and M.-C. Lee. Process kinetics of an expanded granular sludge bed reactor treating sulfate-containing wastewater. *Chemical Engineering Journal*, 170(1):233–240, May 2011. doi: 10.1016/j.cej.2011.03.061.
- D. Chynoweth, S. Svoronos, G. Lyberatos, J. Harmand, P. Pullammanappallil, J. Owens, and J. Peck. Real-time expert system control of anaerobic digestion. *Water Science and Technology*, 30(12):21–29, Dec. 1994.
- C. A. Coello Coello. Evolutionary multi-objective optimization: basic concepts and some applications in pattern recognition. *Lecture Notes in Computer Science - Pattern Recognition*, 6718:22–33, 2011. doi: 10.1007/978-3-642-21587-2_3.
- A. I. Comport, E. Marchand, M. Pressigout, and F. Chaumette. Real-time markerless tracking for augmented reality: the virtual visual servoing framework. *IEEE T Vis Comput Gr*, 12(4):615–28, 2006. doi: 10.1109/TVCG.2006.78.
- R. Cord-Ruwisch, T. I. Mercz, C. Y. Hoh, and G. E. Strong. Dissolved hydrogen concentration as an on-line control parameter for the automated operation and optimization of anaerobic digesters. *Biotechnol Bioeng*, 56(6):626–34, Dec. 1997. doi: 10.1002/(SICI)1097-0290(19971220)56:6<626::AID-BIT5>3.0.CO;2-P.
- D. J. Costello, P. L. Lee, and P. F. Greenfield. Control of anaerobic digesters using Generic Model Control. *Bioprocess Engineering*, 4(3):119–122, Apr. 1989. doi: 10.1007/BF00369760.
- D. D. Cox and S. John. SDO : A Statistical Method for Global Optimization. *Multidisciplinary design optimization*, 2:315–329, 1997.
- A. Criminisi, J. Shotton, and E. Konukoglu. Decision Forests for Classification, Regression, Density Estimation, Manifold Learning and Semi-Supervised Learning. Technical report, Microsoft Research, 2011.
- A. Custódio, M. Emmerich, and J. Madeira. Recent Developments in Derivative-Free Multiobjective Optimisation. *Computational Technology Reviews*, 5:1–30, Sept. 2012. doi: 10.4203/ctr.5.1.
- M. L. Darby, M. Nikolaou, J. Jones, and D. Nicholson. RTO: An overview and assessment of current practice. *Journal of Process Control*, 21(6):874–884, July 2011. doi: 10.1016/j.jprocont.2011.03.009.
- C. L. Davey, H. M. Davey, D. B. Kell, and R. W. Todd. Introduction to the dielectric estimation of cellular biomass in real time, with special emphasis on measurements at high volume fractions. *Analytica Chimica Acta*, 279(1):155–161, July 1993. doi: 10.1016/0003-2670(93)85078-X.

- G. De Souza, D. Odloak, and A. C. Zanin. Real time optimization (RTO) with model predictive control (MPC). *Computers & Chemical Engineering*, 34(12):1999–2006, Dec. 2010. doi: 10.1016/j.compchemeng.2010.07.001.
- K. Deb, A. Pratap, S. Agarwal, and T. Meyarivan. A fast and elitist multiobjective genetic algorithm: NSGA-II. *IEEE T Evolut Comput*, 6(2):182–197, Apr. 2002. doi: 10.1109/4235.996017.
- K. Deb, M. Mohan, and S. Mishra. A fast multi-objective evolutionary algorithm for finding well-spread pareto-optimal solutions. Technical report, Indian Institute of Technology, Kanpur, 2003.
- M. Denac, K. Griffin, P. Lee, and P. Greenfield. Selection of controlled variables for a high rate anaerobic reactor. *Environmental Technology Letters*, 9(10):1029–1040, Oct. 1988. doi: 10.1080/09593338809384666.
- M. Denac, P. Lee, R. Newell, and P. Greenfield. Automatic control of effluent quality from a high-rate anaerobic treatment system. *Water Research*, 24(5):583–586, May 1990. doi: 10.1016/0043-1354(90)90190-H.
- M. Denil, D. Matheson, and N. de Freitas. Consistency of Online Random Forests. In *30th International Conference on Machine Learning*, page 21, Atlanta, 2013.
- R. Dewil, J. Lauers, L. Appels, G. Gins, J. Degève, and J. F. Van Impe. Anaerobic Digestion of Biomass and Waste: Current Trends in Mathematical Modeling. In B. Sergio, editor, *Proceedings of the 18th IFAC World Congress*, number 1969, pages 5024–5033, Aug. 2011. doi: 10.3182/20110828-6-IT-1002.03208.
- M. Diehl, R. Findeisen, S. Schwarzkopf, I. Uslu, F. Allgöwer, H. G. Bock, E.-D. Gilles, and J. P. Schlöder. An Efficient Algorithm for Nonlinear Model Predictive Control of Large-Scale Systems Part I: Description of the Method (Ein effizienter Algorithmus für die nichtlineare prädiktive Regelung großer Systeme Teil I: Methodenbeschreibung). *at - Automatisierungstechnik*, 50(12_2002):557, Dec. 2002. doi: 10.1524/auto.2002.50.12.557.
- M. Diehl, R. Findeisen, S. Schwarzkopf, I. Uslu, F. Allgöwer, H. G. Bock, E.-D. Gilles, and J. P. Schlöder. Ein effizienter Algorithmus für die nichtlineare prädiktive Regelung großer Systeme Teil II: Experimentelle Erprobung an einer Destillationskolonne (An Efficient Algorithm for Nonlinear Model Predictive Control of Large-Scale Systems Part II: Experimental. *at - Automatisierungstechnik*, 51(1-2003):22–29, Jan. 2003. doi: 10.1524/auto.51.1.22.18879.
- M. Diehl, H. Bock, H. Diedam, and P. Wieber. Fast direct multiple shooting algorithms for optimal robot control. *Fast Motions in Biomechanics and Robotics*, 340:65–93, 2006a. doi: 10.1007/978-3-540-36119-0_4.
- M. Diehl, P. Kühn, H. Bock, and J. Schlöder. Combined nonlinear model predictive control and moving horizon estimation for a copolymerization process. *Comput Aided Chem Eng*, 21:1527–1532, 2006b. doi: 10.1016/S1570-7946(06)80264-6.
- M. Diehl, P. Kühn, H. G. Bock, and J. P. Schlöder. Schnelle Algorithmen für die Zustands- und Parameterschätzung auf bewegten Horizonten (Fast Algorithms for State and Parameter Estimation on Moving Horizons). *at - Automatisierungstechnik*, 54(12):602–613, Dec. 2006c. doi: 10.1524/auto.2006.54.12.602.
- N. Dimitrova and M. Krastanov. Nonlinear adaptive control of a model of an uncertain fermentation process. *Int J Robust Nonlin*, 20(9):1001–1009, 2009. doi: 10.1002/rnc.1503.

- DIN. DIN 38404-4 - Bestimmung der Temperatur (determination of temperature). Technical Report 0004, Deutsches Institut für Normung e.V., Berlin, 1976.
- DIN. DIN 38406-5 - Bestimmung des Ammonium-Stickstoffs (E5) (determination of ammonia-nitrogen). Technical report, Deutsches Institut für Normung e.V., 1983.
- DIN. DIN 51857 - Berechnung von Brennwert, Heizwert, Dichte, relativer Dichte und Wobbeindex von Gasen und Gasgemischen (Calculation of calorific value, density, relative density and Wobbe index of pure gases and gas mixtures). Technical Report 0009, Deutsches Institut für Normung e.V., 1997.
- DIN. DIN EN 12176 - Bestimmung des pH-Wertes (Determination of pH-value). Technical Report 2306, Deutsches Institut für Normung e.V., Berlin, 1998.
- DIN. DIN EN 12880 - Bestimmung des Trockenrückstandes und des Wassergehalts (Determination of dry residue and water content). Technical Report 2306, Deutsches Institut für Normung e.V., 2001a.
- DIN. DIN EN 12879 - Bestimmung des Glühverlustes der Trockenmasse (Determination of the loss on ignition of dry mass). Technical Report 2306, Deutsches Institut für Normung e.V., 2001b.
- DIN. DIN ISO 15705 - Bestimmung des chemischen Sauerstoffbedarfs (Determination of the chemical oxygen demand index). Technical Report 2212, Deutsches Institut für Normung e.V., 2003.
- DIN. DIN 38409-7 - Bestimmung der Säure- und Basekapazität (Determination of acid and base capacity). Technical report, Deutsches Institut für Normung e.V., Berlin, 2005.
- D. Dochain and G. Bastin. Stable adaptive controllers for waste treatment by anaerobic digestion. *Environ Technol Lett*, 6(12):584–593, Dec. 1985. doi: 10.1080/09593338509384379.
- D. Dochain and M. Perrier. Control design for nonlinear wastewater treatment processes. *Water Science & Technology*, 28(11-12):283–293, Mar. 1993.
- D. Dochain and P. Vanrolleghem. *Dynamical Modelling and Estimation in Wastewater Treatment Processes*. IWA Publishing, Cornwall, UK, 1 edition, 2001.
- D. Dochain, M. Perrier, and A. Pauss. Adaptive control of the hydrogen concentration in anaerobic digestion. *Ind Eng Chem Res*, 30(1):129–136, Jan. 1991. doi: 10.1021/ie00049a020.
- A. Donoso-Bravo, J. Mailier, C. Martin, J. Rodríguez, C. A. Aceves-Lara, and A. Vande Wouwer. Model selection, identification and validation in anaerobic digestion: a review. *Water Res*, 45(17):5347–64, Nov. 2011. doi: 10.1016/j.watres.2011.08.059.
- A. Donoso-Bravo, W. M. K. R. T. W. Bandara, H. Satoh, and G. Ruiz-Filippi. Explicit temperature-based model for anaerobic digestion: application in domestic wastewater treatment in a UASB reactor. *Bioresource technology*, 133:437–42, Apr. 2013. doi: 10.1016/j.biortech.2013.01.174.
- R. O. Duda, P. E. Hart, and D. G. Stork. *Pattern Classification (2nd Edition)*. Wiley-Interscience, 2000.
- F. Ehlinger, Y. Escoffier, J. Couderc, J. Leyris, and R. Moletta. Development of an automatic control system for monitoring an anaerobic fluidized-bed. *Water science and technology*, 29(10-11):289–295, May 1994.

- M. Ellis and P. D. Christofides. Integrating dynamic economic optimization and model predictive control for optimal operation of nonlinear process systems. *Control Engineering Practice*, 22:242–251, Jan. 2014. doi: 10.1016/j.conengprac.2013.02.016.
- C. Emmanouilides and L. Petrou. Identification and control of anaerobic digesters using adaptive, on-line trained neural networks. *Computers & Chemical Engineering*, 21(1):113–143, Sept. 1996. doi: 10.1016/0098-1354(95)00244-8.
- M. Emmerich, N. Beume, and B. Naujoks. An EMO algorithm using the hypervolume measure as selection criterion. *Lecture Notes in Computer Science - Evolutionary Multi-Criterion Optimization*, 3410:62–76, 2005. doi: 10.1007/978-3-540-31880-4_5.
- M. Emmerich, K. Giannakoglou, and B. Naujoks. Single- and multiobjective evolutionary optimization assisted by Gaussian random field metamodells. *IEEE T Evolut Comput*, 10(4):421–439, Aug. 2006. doi: 10.1109/TEVC.2005.859463.
- S. Engell. Feedback control for optimal process operation. *Journal of Process Control*, 17(3):203–219, Mar. 2007. doi: 10.1016/j.jprocont.2006.10.011.
- M. Esfahani. Neuro-fuzzy approach for short-term electricity price forecasting developed MATLAB-based software. *Fuzzy Information and Engineering*, 3(4):339–350, Dec. 2011. doi: 10.1007/s12543-011-0089-2.
- M. Estaben, M. Polit, and J. Steyer. Fuzzy control for an anaerobic digester. *Control Eng Pract*, 5(9):1303–1310, Sept. 1997. doi: 10.1016/S0967-0661(97)84369-9.
- Eurostat. Share of energy from renewable sources, 2013.
- H. Feitkenhauer, S. J. Von, and U. Meyer. On-line titration of volatile fatty acids for the process control of anaerobic digestion plants. *Water Res*, 36(1):212–8, Jan. 2002.
- A. P. Ferreira, L. M. Vieira, J. P. Cardoso, and J. C. Menezes. Evaluation of a new annular capacitance probe for biomass monitoring in industrial pilot-scale fermentations. *J Biotechnol*, 116(4):403–9, Apr. 2005. doi: 10.1016/j.jbiotec.2004.12.006.
- R. Findeisen, L. Imsland, F. Allgöwer, and B. A. Foss. State and Output Feedback Nonlinear Model Predictive Control: An Overview. *European Journal of Control*, 9(2-3):190–206, June 2003. doi: 10.3166/ejc.9.190-206.
- M. Fleischer. The measure of Pareto optima applications to multi-objective metaheuristics. *Lecture Notes in Computer Science - Evolutionary Multi-Criterion Optimization*, 2632:519–533, 2003. doi: 10.1007/3-540-36970-8_37.
- P. Fleming and R. Purshouse. Evolutionary algorithms in control systems engineering: a survey. *Control Eng Pract*, 10(11):1223–1241, Nov. 2002. doi: 10.1016/S0967-0661(02)00081-3.
- J. Flores, B. Arcay, and J. Arias. An intelligent system for distributed control of an anaerobic wastewater treatment process. *Engineering Applications of Artificial Intelligence*, 13(4):485–494, Aug. 2000a. doi: 10.1016/S0952-1976(00)00015-4.
- J. Flores, B. Arcay, and J. Dafonte. Knowledge-based system for telecontrol of anaerobic wastewater treatment plants. *Expert Systems*, 17(2):71–80, May 2000b. doi: 10.1111/1468-0394.00129.
- R. A. Flores-Estrella, G. Quiroz, H. O. Méndez-Acosta, and A. R. Femat. Hinfy control of anaerobic digester for winery industry wastewater treatment. *Ind Eng Chem Res*, page 130127193624002, Jan. 2013. doi: 10.1021/ie302233t.

- A. Flores-Tlacuahuac, P. Morales, and M. Rivera-Toledo. Multiobjective Nonlinear Model Predictive Control of a Class of Chemical Reactors. *Ind Eng Chem Res*, 51(17):5891–5899, May 2012. doi: 10.1021/ie201742e.
- FNR. Mediathek FNR, 2013.
- A. I. Forrester, A. Sóbester, and A. J. Keane. Multi-fidelity optimization via surrogate modelling. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 463(2088):3251–3269, Dec. 2007. doi: 10.1098/rspa.2007.1900.
- L. Fortuna, S. Graziani, A. Rizzo, and M. G. Xibilia. *Soft sensors for monitoring and control of industrial processes*. Springer-Verlag, London, 2007.
- M. Franke, A. Weger, and M. Faulstich. Prozessregelung von Vergärungsanlagen mit Hilfe des Parameters Wasserstoff. In *Gülzower Fachgespräche: Band 27 Messen, Steuern, Regeln bei der Biogaserzeugung*, number Fkz 22016200, pages 121–145, Gülzow, 2008. FNR.
- D. Gaida, C. Wolf, T. Bäck, and M. Bongards. Nonlinear model predictive substrate feed control of biogas plants. In *2012 20th Mediterranean Conference on Control & Automation (MED)*, pages 652–657, Barcelona, July 2012a. IEEE. doi: 10.1109/MED.2012.6265712.
- D. Gaida, C. Wolf, C. Meyer, A. Stuhlsatz, J. Lippel, T. Bäck, M. Bongards, and S. McLoone. State estimation for anaerobic digesters using the ADM1. *Water Sci Technol*, 66(5):1088–95, Jan. 2012b. doi: 10.2166/wst.2012.286.
- C. Garcia, F. Molina, E. Roca, and J. M. Lema. Fuzzy-Based Control of an Anaerobic Reactor Treating Wastewaters Containing Ethanol and Carbohydrates. *Ind Eng Chem Res*, 46(21):6707–6715, Oct. 2007. doi: 10.1021/ie0617001.
- C. García-Diéguez, F. Molina, and E. Roca. Multi-objective cascade controller for an anaerobic digester. *Process Biochemistry*, 46(4):900–909, Apr. 2011. doi: 10.1016/j.procbio.2010.12.015.
- P. García-Sandoval, V. González-Álvarez, and B. Castillo-Toledo. Control of a bioreactor with sampled delayed measurement. In *10th International IFAC Symposium on Computer Applications in Biotechnology*, volume 1, pages 315–320, Cancún, Mexico, 2007. IFAC.
- H. N. Gavala, I. Angelidaki, and B. K. Ahring. Kinetics and modeling of anaerobic digestion process. *Adv Biochem Eng Biot*, 81:57–93, Jan. 2003.
- K. G. Gebremedhin, B. Wu, C. Gooch, P. Wright, and S. Inglis. Heat Transfer Model for Plug Flow Anaerobic Digesters. *Transactions of ASAE*, 48(2):777–785, 2005.
- T. Gehring, K. Koch, H. Horn, and M. Wichern. Einsatz von mathematischen Prozessmodellen zur Optimierung des anaeroben Abbauprozesses (Application of mathematical models for optimization of the anaerobic digestion process). In S. Köhler, editor, *Bornimer Agrartechnische Berichte Heft 68*, volume 1, pages 96–113, Potsdam-Bornim, 2009. ATB.
- M. H. Gerardi. *The Microbiology of Anaerobic Digesters*. Wiley-Interscience, Hoboken, NJ, USA, 2003.
- M. Gerber. *Ganzheitliche stoffliche und energetische Modellierung des Biogasbildungsprozesses*. Dissertation, Ruhr-Universität Bochum, 2009.

- M. Gerber and R. Span. An analysis of available mathematical models for anaerobic digestion of organic substances for production of biogas. In *IGU Research Conference*, Paris, 2008.
- R. Girault, P. Rousseau, J. P. Steyer, N. Bernet, and F. Béline. Combination of batch experiments with continuous reactor data for ADM1 calibration: application to anaerobic digestion of pig slurry. *Water Sci Technol*, 63(11):2575–82, Jan. 2011.
- S. Graef and J. Andrews. Stability and control of anaerobic digestion. *Journal (Water Pollution Control Federation)*, 46(4):666–683, 1974.
- S. P. Graef. *Dynamics and control strategies for the anaerobic digestion*. Dissertation, Clemson University, 1972.
- M. Grepmeier. *Experimentelle Untersuchungen an einer zweistufigen fuzzy-geregelten anaeroben Abwasserreinigungsanlage mit neuartigem Festbettmaterial*. Doktoringenieur, TU Munich, 2002.
- M. S. Grewal and A. P. Andrews. *Kalman Filtering: Theory and Practice Using MATLAB*, volume 5. John Wiley & Sons, Inc., Hoboken, NJ, USA, 3rd edition, Aug. 2008. doi: 10.1002/9780470377819.
- F. Grognaud and O. Bernard. Stability analysis of a wastewater treatment plant with saturated control. *Water Science and Technology*, 53(1):149–57, Jan. 2006.
- W. Gujer and A. J. B. Zehnder. Conversion Processes in Anaerobic Digestion. *Water Sci Technol*, 15(8-9):127–167, 1983.
- K. J. Gurubel, E. N. Sanchez, S. Carlos-Hernandez, and F. Ornelas-Tellez. PSO hybrid intelligent inverse optimal control for an anaerobic process. In *2013 IEEE Congress on Evolutionary Computation*, pages 876–883. IEEE, June 2013. doi: 10.1109/CEC.2013.6557660.
- A. Guwy, F. Hawkes, S. Wilcox, and D. Hawkes. Neural network and on-off control of bicarbonate alkalinity in a fluidised-bed anaerobic digester. *Water Research*, 31(8):2019–2025, Aug. 1997. doi: 10.1016/S0043-1354(97)00016-X.
- N. Hansen. The CMA evolution strategy: a comparing review. *Towards a new evolutionary computation*, 192(2006):75–102, 2006. doi: 10.1007/3-540-32494-1_4.
- J. Harmand, A. G. Manh, and J. P. Steyer. Identification and disturbance accommodating control of a fluidized bed anaerobic digester. *Bioprocess Engineering*, 23(2):0177–0185, Aug. 2000. doi: 10.1007/s004499900147.
- J. Harmon, P. Pullamanapallil, G. Lyberatos, S. Svoronos, and D. Chynoweth. Stabilization of a Continuous Glucose-Fed Anaerobic Digester via Feed Rate Control. In *American Control Conference*, pages 2156–2160, 1990.
- J. Harmon, S. Svoronos, G. Lyberatos, and D. Chynoweth. Adaptive temperature optimization of continuous anaerobic digesters. *Biomass and Bioenergy*, 5(3-4):279–288, Jan. 1993. doi: 10.1016/0961-9534(93)90077-H.
- E. L. Haseltine and J. B. Rawlings. Critical Evaluation of Extended Kalman Filtering and Moving-Horizon Estimation. *Ind Eng Chem*, 44(8):2451–2460, Apr. 2005. doi: 10.1021/ie034308l.
- E. Heinzle, I. J. Dunn, and G. B. Ryhiner. Modeling and control for anaerobic wastewater treatment. *Bioprocess Design and Control*, 48(Advances in Biochemical Engineering/Biotechnology):79–114, 1993. doi: 10.1007/BFb0007193.

- M. Henze and P. Harremoës. Anaerobic Treatment of Wastewater in Fixed Film Reactors - A Literature Review. *Water Sci Technol*, 15(8-9):1-101, Feb. 1983.
- M. Henze, W. Gujer, T. Mino, and M. C. M. van Loosdrecht. *Activated Sludge Models ASM1, ASM2, ASM2d and ASM3*. IWA Publishing, London, 2000.
- R. F. Hickey, W.-M. Wu, M. C. Veiga, and R. Jones. Start-Up, Operation, Monitoring and Control of High-Rate Anaerobic Treatment Systems. *Water Sci Technol*, 24(8): 207-255, Mar. 1991.
- N. Hilgert, J. Harmand, J.-P. Steyer, and J.-P. Vila. Nonparametric identification and adaptive control of an anaerobic fluidized bed digester. *Control Engineering Practice*, 8(4):367-376, Apr. 2000. doi: 10.1016/S0967-0661(99)00165-3.
- D. Hill, S. Cobb, and J. Bolte. Using volatile fatty acid relationships to predict anaerobic digester failure. *Trans. ASAE; (United States)*, 30(2):496-501, Jan. 1987.
- G. E. Hinton, S. Osindero, and Y.-W. Teh. A fast learning algorithm for deep belief nets. *Neural comput*, 18(7):1527-54, July 2006. doi: 10.1162/neco.2006.18.7.1527.
- J. B. Holm-Nielsen, T. Al Seadi, and P. Oleskowicz-Popiel. The future of anaerobic digestion and biogas utilization. *Bioresour Technol*, 100(22):5478-84, Nov. 2009. doi: 10.1016/j.biortech.2008.12.046.
- P. Holubar, L. Zani, M. Hager, W. Fröschl, Z. Radak, and R. Braun. Advanced controlling of anaerobic digestion by means of hierarchical neural networks. *Water research*, 36(10):2582-8, May 2002.
- P. Holubar, L. Zani, M. Hager, W. Fröschl, Z. Radak, and R. Braun. Start-up and recovery of a biogas-reactor using a hierarchical neural network-based control tool. *J Chem Technol Biot*, 78(8):847-854, Aug. 2003. doi: 10.1002/jctb.854.
- R. Huang, L. T. Biegler, and S. C. Patwardhan. Fast Offset-Free Nonlinear Model Predictive Control Based on Moving Horizon Estimation. *Industrial & Engineering Chemistry Research*, 49(17):7882-7890, Sept. 2010. doi: 10.1021/ie901945y.
- O. Ince, F. G. Babuna, B. Kasapgil, and G. K. Anderson. Experimental Determination of the Inert Soluble COD Fraction of a Brewery Wastewater under Anaerobic Conditions. *Environ Technol*, 19(4):437-442, Apr. 1998. doi: 10.1080/09593331908616700.
- J. Iza, E. Colleran, J. M Paris, and W.-M. Wu. International Workshop on Anaerobic Treatment Technology for Municipal and Industrial Wastewaters: Summary Paper. *Water Science & Technology*, 24(8):1-16, Mar. 1991.
- A. Jaiahtilal. randomforest-matlab - Random Forest (Regression, Classification and Clustering) implementation for MATLAB (and Standalone), 2010.
- E. A. Jáuregui-Medina, V. Alcaraz-González, H. O. Méndez-Acosta, and V. González-Alvarez. Observer-based input estimation in continuous anaerobic wastewater treatment processes. *Water Sci Technol*, 60(3):805-12, Jan. 2009. doi: 10.2166/wst.2009.354.
- H.-S. Jeong, C.-W. Suh, J.-L. Lim, S.-H. Lee, and H.-S. Shin. Analysis and application of ADM1 for anaerobic methane production. *Bioprocess and biosystems engineering*, 27(2):81-9, Apr. 2005. doi: 10.1007/s00449-004-0370-4.

- U. Jeppsson, M.-N. Pons, I. Nopens, J. Alex, J. B. Copp, K. V. Gernaey, C. Rosen, J.-P. Steyer, and P. A. Vanrolleghem. Benchmark simulation model no 2: general protocol and exploratory case studies. *Water Sci Technol*, 56(8):67–78, Jan. 2007. doi: 10.2166/wst.2007.604.
- R. Jin, W. Chen, and A. Sudjianto. An efficient algorithm for constructing optimal design of computer experiments. *Journal of Statistical Planning and Inference*, 134(1):268–287, Sept. 2005. doi: 10.1016/j.jspi.2004.02.014.
- T. Johansen. Introduction to Nonlinear Model Predictive Control and Moving Horizon Estimation. In *Selected Topics on Constrained and Nonlinear Control*, number 1, chapter 5, pages 1–53. 2011.
- K. A. Johnson, A. D. Wheatley, and C. J. Fell. An application of an adaptive control algorithm for the anaerobic treatment of industrial effluent. *Process safety and environmental protection*, 73(3):203–211, 1995.
- D. Jones, M. Schonlau, and W. Welch. Efficient global optimization of expensive black-box functions. *Journal of Global optimization*, 13(4):455–492, 1998. doi: 10.1023/A:1008306431147.
- R. Jones, J. MacGregor, K. Murphy, and E. Hall. Towards a Useful Dynamic Model of the Anaerobic Wastewater Treatment Process: A Practical Illustration of Process Identification. *Water Sci Technol*, 25(7):61–71, Mar. 1992.
- R. M. Jones, J. F. Macgregor, and K. L. Murphy. State estimation in wastewater engineering: Application to an anaerobic process. *Environ Monit Assess*, 13(2-3): 271–282, Nov. 1989. doi: 10.1007/BF00394233.
- P. Karlson, D. Doenecke, J. Koolman, G. Fuchs, and W. Gerok. *Karlsons Biochemie und Pathologie [Hardcover]*. Thieme Georg Verlag, 15th edition, 2005.
- J. Kauder, N. Boes, C. Pasel, and J.-D. Herbell. Combining Models ADM1 and ASM2d in a Sequencing Batch Reactor Simulation. *Chemical Engineering & Technology*, 30(8):1100–1112, Aug. 2007. doi: 10.1002/ceat.200700045.
- R. Kleerebezem and M. C. M. Van Loosdrecht. Waste characterization for implementation in ADM1. *Water Sci Technol*, 54(4):167–74, Jan. 2006.
- J. Knowles. ParEGO: a hybrid algorithm with on-line landscape approximation for expensive multiobjective optimization problems. *IEEE Transactions on Evolutionary Computation*, 10(1):50–66, Feb. 2006. doi: 10.1109/TEVC.2005.851274.
- J. Knowles, D. Corne, and M. Fleischer. Bounded archiving using the lebesgue measure. In *The 2003 Congress on Evolutionary Computation, 2003. CEC '03.*, volume 4, pages 2490–2497. Ieee, 2003. doi: 10.1109/CEC.2003.1299401.
- K. Koch. *Verfahrenstechnische Untersuchungen und mathematische Modellierung der Prozesse bei der Vergärung von Grassilage*. Dissertation, Technische Universität München, 2010.
- K. Koch, M. Wichern, M. Lübken, and H. Horn. Mono fermentation of grass silage by means of loop reactors. *Bioresource technology*, 100(23):5934–40, Dec. 2009. doi: 10.1016/j.biortech.2009.06.020.
- K. Koch, M. Lübken, T. Gehring, M. Wichern, and H. Horn. Biogas from grass silage - Measurements and modeling with ADM1. *Bioresource technology*, 101(21):8158–65, Nov. 2010. doi: 10.1016/j.biortech.2010.06.009.

- T. Kottas, Y. Boutalis, V. Diamantis, O. Kosmidou, and A. Aivasidis. A Fuzzy Cognitive Network Based Control Scheme for An Anaerobic Digestion Process. In *14th Mediterranean Conference on Control and Automation*, pages 1–7. IEEE, June 2006. doi: 10.1109/MED.2006.328850.
- C. Kravaris and G. Savoglidis. Tracking the singular arc of a continuous bioreactor using sliding mode control. *Journal of the Franklin Institute*, 349(4):1583–1601, May 2012. doi: 10.1016/j.franklin.2011.06.011.
- J. W. Kruisselbrink. *Evolution Strategies for Robust Optimization*. Phd, Universiteit Leiden, 2012.
- O. Kujawski and H. Steinmetz. Development of instrumentation systems as a base for control of digestion process stability in full-scale agricultural and industrial biogas plants. *Water Sci Technol*, 60(8):2055–63, Jan. 2009. doi: 10.2166/wst.2009.531.
- J. C. Lagarias, J. A. Reeds, M. H. Wright, and P. E. Wright. Convergence Properties of the Nelder–Mead Simplex Method in Low Dimensions. *SIAM Journal on Optimization*, 9(1):112–147, Jan. 1998. doi: 10.1137/S1052623496303470.
- G. Langergraber, N. Fleischmann, F. Hofstaedter, and A. Weingartner. Monitoring of a paper mill wastewater treatment plant using UV/VIS spectroscopy. *Water Sci Technol*, 49(1):9–14, Jan. 2004.
- J. Lauwers, L. Appels, I. P. Thompson, J. Degève, J. F. Van Impe, and R. Dewil. Mathematical modelling of anaerobic digestion of biomass and waste: Power and limitations. *Progress in Energy and Combustion Science*, 39(4):383–402, 2013.
- M.-Y. Lee, C.-W. Suh, Y.-T. Ahn, and H.-S. Shin. Variation of ADM1 by using temperature-phased anaerobic digestion (TPAD) operation. *Bioresource technology*, 100(11):2816–22, June 2009. doi: 10.1016/j.biortech.2008.12.025.
- G. Lettinga, A. F. M. van Velsen, S. W. Hobma, W. de Zeeuw, and A. Klapwijk. Use of the upflow sludge blanket (USB) reactor concept for biological wastewater treatment, especially for anaerobic treatment. *Biotechnology and Bioengineering*, 22(4):699–734, Apr. 1980. doi: 10.1002/bit.260220402.
- H. Lindorfer, R. Braun, and R. Kirchmayr. Self-heating of anaerobic digesters using energy crops. *Water Sci Technol*, 53(8):159–66, Jan. 2006.
- J. Liu, G. Olsson, and B. Mattiasson. Monitoring and control of an anaerobic upflow fixed-bed reactor for high-loading-rate operation and rejection of disturbances. *Biotechnology and bioengineering*, 87(1):43–53, July 2004a. doi: 10.1002/bit.20088.
- J. Liu, G. Olsson, and B. Mattiasson. Control of an anaerobic reactor towards maximum biogas production. *Water Sci Technol*, 50(11):189–98, Jan. 2004b.
- J. Liu, G. Olsson, and B. Mattiasson. Extremum-seeking with variable gain control for intensifying biogas production in anaerobic fermentation. *Water Sci Technol*, 53(4-5):35–44, Jan. 2006.
- Y. Liu, H.-L. Xu, S.-F. Yang, and J.-H. Tay. Mechanisms and models for anaerobic granulation in upflow anaerobic sludge blanket reactor. *Water Res*, 37(3):661–73, Feb. 2003.
- M. Lübken. *Mathematical modeling of anaerobic digestion processes*. Dissertation, Technische Universität München, 2009.

- M. Lübken, M. Wichern, F. Bischof, S. Prectl, and H. Horn. Development of an empirical mathematical model for describing and optimizing the hygiene potential of a thermophilic anaerobic bioreactor treating faeces. *Water Sci Technol*, 55(7):95, Apr. 2007a. doi: 10.2166/wst.2007.132.
- M. Lübken, M. Wichern, M. Schlattmann, A. Gronauer, and H. Horn. Modelling the energy balance of an anaerobic digester fed with cattle manure and renewable energy crops. *Water Res*, 41(18):4085–96, Oct. 2007b. doi: 10.1016/j.watres.2007.05.061.
- M. Lübken, T. Gehring, and M. Wichern. Microbiological fermentation of lignocellulosic biomass: current state and prospects of mathematical modeling. *Applied microbiology and biotechnology*, 85(6):1643–52, Feb. 2010. doi: 10.1007/s00253-009-2365-1.
- M. Madsen, J. B. Holm-Nielsen, and K. H. Esbensen. Monitoring of anaerobic digestion processes: A review perspective. *Renewable and Sustainable Energy Reviews*, 15(6): 3141–3155, Aug. 2011. doi: 10.1016/j.rser.2011.04.026.
- U. Maeder, F. Borrelli, and M. Morari. Linear offset-free Model Predictive Control. *Automatica*, 45(10):2214–2222, 2009.
- L. Mailleret and O. Bernard. A simple robust controller to stabilise an anaerobic digestion process. In *Proceedings of the 8th Conference on Computer Applications in Biotechnology*, pages 213–218, 2001.
- L. Mailleret, O. Bernard, and J. P. Steyer. Robust regulation of anaerobic digestion processes. *Water Science and Technology*, 48(6):87–94, Jan. 2003.
- L. Mailleret, O. Bernard, and J.-P. Steyer. Nonlinear adaptive control for bioreactors with unknown kinetics. *Automatica*, 40(8):1379–1385, Aug. 2004. doi: 10.1016/j.automatica.2004.01.030.
- U. Marchaim and C. Krause. Propionic to acetic acid ratios in overloaded anaerobic digestion. *Bioresource Technol*, 43(3):195–203, Jan. 1993. doi: 10.1016/0960-8524(93)90031-6.
- N. Marcos, M. Guay, and D. Dochain. Output feedback adaptive extremum seeking control of a continuous stirred tank bioreactor with Monod’s kinetics. *Journal of Process Control*, 14(7):807–818, Oct. 2004a. doi: 10.1016/j.jprocont.2003.12.002.
- N. Marcos, M. Guay, D. Dochain, and T. Zhang. Adaptive extremum-seeking control of a continuous stirred tank bioreactor with Haldane’s Kinetics. *Journal of Process Control*, 14(3):317–328, Apr. 2004b. doi: 10.1016/S0959-1524(03)00070-2.
- S. Marsili-Libelli and S. Beni. Shock load modelling in the anaerobic digestion process. *Ecol Modell*, 84(1-3):215–232, Jan. 1996. doi: 10.1016/0304-3800(94)00125-1.
- S. Marsili-Libelli and A. Müller. Adaptive fuzzy pattern recognition in the anaerobic digestion process. *Pattern Recognition Letters*, 17(6):651–659, May 1996. doi: 10.1016/0167-8655(96)00030-X.
- A. Martinez-Sibaja, R. Posada-Gomez, A. Alvarado-Lassman, and A. Sebastia-Cortes. Cascade Fuzzy Logic Controller for an Anaerobic Digester. In *Electronics, Robotics and Automotive Mechanics Conference (CERMA 2007)*, pages 395–399, Morelos, Sept. 2007. IEEE. doi: 10.1109/CERMA.2007.4367719.
- D. Mayne, J. Rawlings, C. Rao, and P. Scokaert. Constrained model predictive control: Stability and optimality. *Automatica*, 36(6):789–814, June 2000. doi: 10.1016/S0005-1098(99)00214-9.

- P. McKendry. Energy production from biomass (part 1): overview of biomass. *Bioresource Technol*, 83(1):37–46, May 2002. doi: 10.1016/S0960-8524(01)00118-3.
- H. Méndez-Acosta, D. Campos-Delgado, and R. Femat. Intelligent control of an anaerobic digester: fuzzy-based gain scheduling for a geometrical approach. In *Proceedings of the 2003 IEEE International Symposium on Intelligent Control ISIC-03*, pages 298–303. IEEE, 2003. doi: 10.1109/ISIC.2003.1254650.
- H. Méndez-Acosta, D. Campos-Delgado, R. Femat, and V. González-Alvarez. A robust feedforward/feedback control for an anaerobic digester. *Comput. Chem. Eng.*, 29(7):1613–1623, June 2005. doi: 10.1016/j.compchemeng.2005.01.005.
- H. Méndez-Acosta, B. Palacios-Ruiz, J. Steyer, V. Alcaraz-González, E. Latrille, and V. González-Alvarez. Nonlinear approach for the VFA regulation in an anaerobic digester. In P. Michel, editor, *10th International IFAC Symposium on Computer Applications in Biotechnology*, volume 1, pages 79–84, June 2007a. doi: 10.3182/20070604-3-MX-2914.00015.
- H. Méndez-Acosta, B. Palacios-Ruiz, V. Alcaraz-González, V. González-Álvarez, and J. García-Sandoval. A robust control scheme to improve the stability of anaerobic digestion processes. *Journal of Process Control*, 20(4):375–383, Apr. 2010. doi: 10.1016/j.jprocont.2010.01.006.
- H. O. Méndez-Acosta, R. Femat, and D. U. Campos-Delgado. Improving the Performance on the Chemical Oxygen Demand Regulation in Anaerobic Digestion. *Ind Eng Chem Res*, 43(1):95–104, Jan. 2004. doi: 10.1021/ie030298c.
- H. O. Méndez-Acosta, J. P. Steyer, R. Femat, and V. González-Alvarez. Robust Nonlinear Control of a Pilot-Scale Anaerobic Digester. *Lect Notes Contr Inf*, 361/2007:165–199, 2007b. doi: 10.1007/978-3-540-73188-7_6.
- H. O. Méndez-Acosta, B. Palacios-Ruiz, V. Alcaraz-González, J.-P. Steyer, V. González-Álvarez, and E. Latrille. Robust Control of Volatile Fatty Acids in Anaerobic Digestion Processes. *Ind Eng Chem Res*, 47(20):7715–7720, Oct. 2008. doi: 10.1021/ie800256e.
- H. O. Méndez-Acosta, J. P. García-Sandoval, V. González-Álvarez, V. Alcaraz-González, and J. A. Jáuregui-Jáuregui. Regulation of the organic pollution level in anaerobic digesters by using off-line COD measurements. *Bioresource Technol*, 102(17):7666–72, Sept. 2011. doi: 10.1016/j.biortech.2011.05.053.
- J. Mockus, V. Tiesis, and A. Zilinskas. The application of Bayesian methods for seeking the extremum. *Towards Global Optimization*, 2:117–129, 1978.
- R. Moletta, Y. Escoffier, F. Ehlinger, J. Coudert, and J. Leyris. On-line automatic control system for monitoring an anaerobic fluidized-bed reactor: response to organic overload. *Water Sci Technol*, 30(12):11–20, Dec. 1994.
- F. Molina, M. Castellano, C. García, E. Roca, and J. M. Lema. Selection of variables for on-line monitoring, diagnosis, and control of anaerobic digestion processes. *Water Science and Technology*, 60(3):615–22, Jan. 2009. doi: 10.2166/wst.2009.379.
- O. Monroy, J. Alvarez-Ramirez, F. Cuervo, and R. Femat. An Adaptive Strategy To Control Anaerobic Digesters for Wastewater Treatment. *Industrial & Engineering Chemistry Research*, 35(10):3442–3446, Jan. 1996. doi: 10.1021/ie960238p.

- J. L. Montiel-Escobar, V. Alcaraz-González, H. O. Méndez-Acosta, and V. González-Álvarez. ADM1-Based Robust Interval Observer for Anaerobic Digestion Processes. *CLEAN - Soil, Air, Water*, 40(9):933–940, Sept. 2012. doi: 10.1002/clen.201100718.
- M. Morari and J. H. Lee. Model predictive control: past, present and future. *Comput. Chem. Eng.*, 23(4-5):667–682, May 1999. doi: 10.1016/S0098-1354(98)00301-9.
- M. Morari and U. Maeder. Nonlinear offset-free model predictive control. *Automatica*, 48(9):2059–2067, 2012.
- E. Morel, B. Tartakovsky, S. Guiot, and M. Perrier. Design of a multi-model observer-based estimator for anaerobic reactor monitoring. *Comput. Chem. Eng.*, 31(2):78–85, Dec. 2006a. doi: 10.1016/j.compchemeng.2006.05.003.
- E. Morel, B. Tartakovsky, S. R. Guiot, and M. Perrier. ADM1 application for tuning and performance analysis of a multi-model observer-based estimator. *Water Sci Technol*, 54(4):93–100, Jan. 2006b.
- S. Mu, Y. Zeng, and P. Wu. Multivariable control of anaerobic reactor by using external recirculation and bypass ratio. *Journal of Chemical Technology & Biotechnology*, 83(6):892–903, June 2008. doi: 10.1002/jctb.1888.
- S. J. Mu, Y. Zeng, B. Tartakovsky, and P. Wu. Simulation and Control of an Upflow Anaerobic Sludge Blanket (UASB) Reactor Using an ADM1-Based Distributed Parameter Model. *Ind Eng Chem Res*, 46(5):1519–1526, Feb. 2007. doi: 10.1021/ie060853l.
- A. Müller, S. Marsili-Libelli, A. Aivasidis, T. Lloyd, S. Kroner, and C. Wandrey. Fuzzy control of disturbances in a wastewater treatment process. *Water Research*, 31(12):3157–3167, Dec. 1997. doi: 10.1016/S0043-1354(97)00215-7.
- E. Murnleitner. *State Detection and Feedback Control of the Anaerobic Wastewater Treatment Using Fuzzy Logic*. Dissertation, Technische Universität München, 2001.
- E. Murnleitner, T. M. Becker, and A. Delgado. State detection and control of overloads in the anaerobic wastewater treatment using fuzzy logic. *Water Res*, 36(1):201–11, Jan. 2002.
- V. Nallathambi Gunaseelan. Anaerobic digestion of biomass for methane production: A review. *Biomass and Bioenergy*, 13(1-2):83–114, Jan. 1997. doi: 10.1016/S0961-9534(97)00020-2.
- J. A. Nelder and R. Mead. A Simplex Method for Function Minimization. *The Computer Journal*, 7(4):308–313, Jan. 1965. doi: 10.1093/comjnl/7.4.308.
- A. M. Nielsen, H. Spanjers, and E. I. P. Volcke. Calculating pH in pig manure taking into account ionic strength. *Water Sci Technol*, 57(11):1785–90, Jan. 2008. doi: 10.2166/wst.2008.099.
- OBSERV’ER. The state of renewable energies in europe - 12th EurObserv’ER Report. Technical Report 0, OBSERV’ER, Paris, 2012.
- M. Ogurek and J. Alex. Überlegungen zur Modellierung mit dem ADM1. In *ifak Workshop: Steuerung, Regelung und Simulation von Biogasanlagen*, Leipzig, 2013. ifak e.V.
- G. Olsson, M. K. Nielsen, and Z. Yuan. *Instrumentation, Control and Automation in Wastewater Systems (Scientific & Technical Report)*. IWA Publishing, 2007.

- A. Ordace, C. Ionescu, T. P. Vanneck, E. I. P. Volcke, I. Nascu, and R. De Keyser. Predictive control of anaerobic digestion of wastewater sludge: a feasibility study. In *Proceedings of the 16th International Conference on System Theory, Control and Computing*, Sinaia, Romania, 2012.
- H. E. Osman. Online random forests based on CorrFS and CorrBE. In *2008 IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops*, pages 1–7, Anchorage, AK, June 2008. IEEE. doi: 10.1109/CVPRW.2008.4563065.
- T. Patterson, S. Esteves, R. Dinsdale, and A. Guwy. Life cycle assessment of biogas infrastructure options on a regional scale. *Bioresource technology*, 102(15):7313–23, Aug. 2011. doi: 10.1016/j.biortech.2011.04.063.
- M. Perrier and D. Dochain. Evaluation of control strategies for anaerobic digestion processes. *International Journal of Adaptive Control and Signal Processing*, 7(4): 309–321, July 1993. doi: 10.1002/acs.4480070408.
- E. Petre, D. Selisteanu, and D. Sendrescu. On adaptive control of an anaerobic digestion bioprocess. In *7th WSEAS International Conference on Systems Theory and Scientific Computation*, pages 7–12, Athens, 2007.
- E. Petre, D. Selisteanu, and D. Sendrescu. Adaptive and robust-adaptive control strategies for anaerobic wastewater treatment bioprocesses. *Chemical Engineering Journal*, 217:363–378, Feb. 2013. doi: 10.1016/j.cej.2012.11.129.
- P. F. Pind, I. Angelidaki, B. K. Ahring, K. Stamatelatos, and G. Lyberatos. Monitoring and control of anaerobic reactors. *Adv Biochem Eng Biot*, 82:135–82, Jan. 2003.
- R. Plank. *Wärmeaustauscher (Handbuch der Kältetechnik Band 6)*. Springer, 1st edition, 1988.
- M. F. Podrutzny and L. van den Berg. Development of a computer control system for anaerobic methane-producing reactors. *Biotechnology and bioengineering*, 26(4): 392–3, Apr. 1984. doi: 10.1002/bit.260260419.
- M. Polihronakis, L. Petrou, and A. Deligiannis. Parameter adaptive control techniques for anaerobic digesters - real-life experiments. *Computers & Chemical Engineering*, 17(12):1167–1179, Dec. 1993. doi: 10.1016/0098-1354(93)80097-7.
- M. Polit, A. Genovesi, and B. Claudet. Fuzzy logic observers for a biological wastewater treatment process. *Appl Numer Math*, 39(2):173–180, Nov. 2001. doi: 10.1016/S0168-9274(01)00098-8.
- A. Polster. *Anwendung des erweiterten KALMAN-Filters zur Zustandsbeobachtung in Biogasanlagen (Application of the extended Kalman filter for state estimation in biogas plants)*. Dissertation, Technische Universität Dresden (Dresden University of Technology), 2009.
- W. Ponweiser, T. Wagner, D. Biermann, and M. Vincze. Multiobjective Optimization on a Limited Budget of Evaluations Using Model-Assisted S-Metric Selection. *Lecture Notes in Computer Science - Parallel Problem Solving from Nature*, 5199:784–794, 2008. doi: 10.1007/978-3-540-87700-4_78.
- W. Pretorius. pH-controlled feed-on-demand for high-rate anaerobic systems. *Water Science and Technology*, 30(8):1–8, Oct. 1994.

- A. Puñal, J. Rodríguez, A. Franco, E. F. Carrasco, E. Roca, and J. M. Lema. Advanced monitoring and control of anaerobic wastewater treatment plants: diagnosis and supervision by a fuzzy-based expert system. *Water Sci Technol*, 43(7):191–8, Jan. 2001.
- A. Puñal, J. Rodríguez, E. F. Carrasco, E. Roca, and J. M. Lema. Expert system for the on-line diagnosis of anaerobic wastewater treatment plants. *Water Sci Technol*, 45(10):195–200, Jan. 2002.
- A. Puñal, L. Palazzotto, J. C. Bouvier, T. Conte, and J. P. Steyer. Automatic control of volatile fatty acids in anaerobic digestion using a fuzzy logic based approach. *Water Science and Technology*, 48(6):103–10, Jan. 2003.
- P. Pullammanappallil, J. Harmon, D. P. Chynoweth, G. Lyberatos, and S. A. Svoronos. Avoiding digester imbalance through real-time expert system control of dilution rate. *Appl Biochem Biotech*, 28-29(1):33–42, Mar. 1991. doi: 10.1007/BF02922587.
- P. C. Pullammanappallil, S. A. Svoronos, D. P. Chynoweth, and G. Lyberatos. Expert system for control of anaerobic digesters. *Biotechnol Bioeng*, 58(1):13–22, Apr. 1998.
- P. C. Pullammanappallil, D. P. Chynoweth, G. Lyberatos, and S. A. Svoronos. Stable performance of anaerobic digestion in the presence of a high concentration of propionic acid. *Bioresource technology*, 78(2):165–9, June 2001.
- S. Qin and T. A. Badgwell. A survey of industrial model predictive control technology. *Control Eng Pract*, 11(7):733–764, July 2003. doi: 10.1016/S0967-0661(02)00186-7.
- J. Rajesh Banu and S. Kaliappan. Treatment of tannery wastewater using hybrid upflow anaerobic sludge blanket reactor. *Journal of Environmental Engineering and Science*, 6(4):415–421, July 2007. doi: 10.1139/s06-063.
- A. Ramakrishnan and R. Y. Surampalli. Performance of anaerobic hybrid reactors for the treatment of complex phenolic wastewaters with biogas recirculation. *Bioresource technology*, 129C(null):26–32, Nov. 2012. doi: 10.1016/j.biortech.2012.11.035.
- C. Rao, J. Rawlings, and D. Mayne. Constrained state estimation for nonlinear discrete-time systems: stability and moving horizon approximations. *IEEE Trans Automat Contr*, 48(2):246–258, Feb. 2003. doi: 10.1109/TAC.2002.808470.
- C. V. Rao. *Moving horizon strategies for the constrained monitoring and control of nonlinear discrete-time systems*. Doctor of philosophy, University of Wisconsin-Madison, 2000.
- A. Rapaport and J. Harmand. Robust regulation of a class of partially observed nonlinear continuous bioreactors. *Journal of Process Control*, 12(2):291–302, Feb. 2002. doi: 10.1016/S0959-1524(01)00029-4.
- A. Raue, C. Kreutz, T. Maiwald, J. Bachmann, M. Schilling, U. Klingmüller, and J. Timmer. Structural and practical identifiability analysis of partially observed dynamical models by exploiting the profile likelihood. *Bioinformatics (Oxford, England)*, 25(15):1923–9, Aug. 2009. doi: 10.1093/bioinformatics/btp358.
- A. Raue, C. Kreutz, T. Maiwald, U. Klingmüller, and J. Timmer. Addressing parameter identifiability by model-based experimentation. *IET systems biology*, 5(2):120–30, Mar. 2011. doi: 10.1049/iet-syb.2010.0061.
- J. B. Rawlings and B. R. Bakshi. Particle filtering and moving horizon estimation. *Comput. Chem. Eng.*, 30(10-12):1529–1541, Sept. 2006. doi: 10.1016/j.compchemeng.2006.05.031.

- K. Reif, S. Günther, E. Yaz, and R. Unbehauen. Stochastic stability of the discrete-time extended Kalman filter. *IEEE Trans Automat Contr*, 44(4):714–728, Apr. 1999. doi: 10.1109/9.754809.
- K. Reif, S. Günther, E. Yaz, and R. Unbehauen. Stochastic stability of the continuous-time extended Kalman filter. *IEE Proceedings - Control Theory and Applications*, 147(1):45–52, Jan. 2000. doi: 10.1049/ip-cta:20000125.
- P. Renard, D. Dochain, G. Bastin, H. Naveau, and E. J. Nyns. Adaptive control of anaerobic digestion processes - a pilot-scale application. *Biotechnology and bioengineering*, 31(4):287–94, Mar. 1988. doi: 10.1002/bit.260310402.
- P. Renard, V. Van Breusegem, M. T. Nguyen, H. Naveau, and E. J. Nyns. Implementation of an adaptive controller for the startup and steady-state running of a biomethanation process operated in the CSTR mode. *Biotechnology and bioengineering*, 38(8):805–12, Oct. 1991. doi: 10.1002/bit.260380802.
- L. Rieger, J. Alex, S. Winkler, M. Boehler, M. Thomann, and H. Siegrist. Progress in sensor technology - progress in process control? Part 1: sensor property investigation and classification. *Water Sci Technol*, 47(2):103–12, Jan. 2003.
- A. Rincon, F. Angulo, and G. Olivar. Control of an anaerobic digester through normal form of fold bifurcation. *J Process Contr*, 19(8):1355–1367, Sept. 2009. doi: 10.1016/j.jprocont.2009.04.006.
- A. Rincón, C. Erazo, and F. Angulo. A robust adaptive controller for an anaerobic digester with saturated input: Guarantees for the boundedness and convergence properties. *J Process Contr*, 22(9):1785–1792, Oct. 2012. doi: 10.1016/j.jprocont.2012.07.014.
- A. Rodriguez, G. Quiroz, J. de Leon, and R. Femat. State and parameter estimation of an anaerobic digester model. In *2011 IEEE International Conference on Automation Science and Engineering*, pages 690–695. IEEE, Aug. 2011. doi: 10.1109/CASE.2011.6042484.
- J. Rodríguez, G. Ruiz, F. Molina, E. Roca, and J. Lema. A hydrogen-based variable-gain controller for anaerobic digestion processes. *Water Science & Technology*, 54(2):57–62, July 2006. doi: 10.2166/wst.2006.486.
- M. Romli, P. Greenfield, and P. Lee. Effect of recycle on a two-phase high-rate anaerobic wastewater treatment system. *Water Research*, 28(2):475–482, Feb. 1994. doi: 10.1016/0043-1354(94)90285-2.
- C. Rosen, U. Jeppsson, L. Rieger, and P. A. Vanrolleghem. Adding realism to simulated sensors and actuators. *Water Sci Technol*, 57(3):337–44, Jan. 2008. doi: 10.2166/wst.2008.130.
- A. Rozzi. Modelling and control of anaerobic digestion processes. *Transactions of the Institute of Measurement and Control*, 6(3):153–159, July 1984. doi: 10.1177/014233128400600306.
- A. Rozzi, A. Di Pinto, and A. Brunetti. Anaerobic process control by bicarbonate monitoring. *Environmental Technology Letters*, 6(12):594–601, Dec. 1985. doi: 10.1080/09593338509384380.
- G. Ryhiner, I. Dunn, E. Heinzle, and S. Rohani. Adaptive on-line optimal control of bioreactors: application to anaerobic degradation. *Journal of Biotechnology*, 22(1-2): 89–105, Jan. 1992. doi: 10.1016/0168-1656(92)90134-U.

- G. B. Ryhiner, E. Heinzle, and I. J. Dunn. Modeling and simulation of anaerobic wastewater treatment and its application to control design: Case whey. *Biotechnology Progress*, 9(3):332–343, May 1993. doi: 10.1021/bp00021a013.
- A. Saffari, C. Leistner, J. Santner, M. Godec, and H. Bischof. On-line Random Forests. In *2009 IEEE 12th International Conference on Computer Vision Workshops, ICCV Workshops*, pages 1393–1400. IEEE, Sept. 2009. doi: 10.1109/ICCVW.2009.5457447.
- V. Saravanan and T. R. Sreekrishnan. Modelling anaerobic biofilm reactors—a review. *J Environ Manage*, 81(1):1–18, Oct. 2006. doi: 10.1016/j.jenvman.2005.10.002.
- M. Sbarciog and A. Vande Wouwer. Some Considerations About Control of Multi-species Anaerobic Digestion Systems. In *7th Vienna International Conference on Mathematical Modelling (MATHMOD)*, 2012.
- M. Sbarciog, M. Loccufier, and A. Vande Wouwer. On the Optimization of Biogas Production in Anaerobic Digestion Systems. In *18th IFAC World Congress*, pages 7150–7155, Milano, 2011.
- M. Sbarciog, M. Loccufier, and A. Vande Wouwer. An optimizing start-up strategy for a bio-methanator. *Bioproc Biosyst Eng*, 35(4):565–78, May 2012a. doi: 10.1007/s00449-011-0629-5.
- M. Sbarciog, J. A. Moreno, and A. Vande Wouwer. A Biogas-Based Switching Control Policy for Anaerobic Digestion Systems. In K. Vinay, editor, *Advanced Control of Chemical Processes*, volume 8, pages 603–608, Furama Riverfront, Singapore, July 2012b. doi: 10.3182/20120710-4-SG-2026.00056.
- P. Scherer, S. Ergun, and O. Schmidt. Entwicklung einer Fuzzy-Logik-Regelung für eine Hochdurchsatz-Biogasanlage: "Telefermentation" zwischen Hamburg und Nordhausen. In *Gülzower Fachgespräche: Band 27 Messen, Steuern, Regeln bei der Biogaserzeugung*, pages 146–171, Gülzow, 2008. FNR.
- P. Scherer, K. Lehmann, O. Schmidt, and B. Demirel. Application of a fuzzy logic control system for continuous anaerobic digestion of low buffered, acidic energy crops as mono-substrate. *Biotechnol Bioeng*, 102(3):736–48, Feb. 2009. doi: 10.1002/bit.22108.
- M. Schlegel, K. Stockmann, T. Binder, and W. Marquardt. Dynamic optimization using adaptive control vector parameterization. *Comput. Chem. Eng.*, 29(8):1731–1751, 2005.
- M. A. Schoen, D. Sperl, M. Gadermaier, M. Goberna, I. Franke-Whittle, H. Insam, J. Ablinger, and B. Wett. Population dynamics at digester overload conditions. *Bioresour Technol*, 100(23):5648–55, Dec. 2009. doi: 10.1016/j.biortech.2009.06.033.
- A. Schuldt and R. Dinse. Übungen zur Tierernährung im Rahmen des Moduls "Tierernährung und Futtermittelkunde" (B-PM15), 2010.
- O. Schütze, X. Esquivel, A. Lara, and C. A. C. Coello. Using the Averaged Hausdorff Distance as a Performance Measure in Evolutionary Multiobjective Optimization. *IEEE T Evolut Comput*, 16(4):504–522, Aug. 2012. doi: 10.1109/TEVC.2011.2161872.
- L. Seghezze, G. Zeeman, J. B. van Lier, H. Hamelers, and G. Lettinga. A review: The anaerobic treatment of sewage in UASB and EGSB reactors. *Bioresour Technology*, 65(3):175–190, Sept. 1998. doi: 10.1016/S0960-8524(98)00046-7.

- J. Seok. Hybrid adaptive optimal control of anaerobic fluidized bed bioreactor for the de-icing waste treatment. *Journal of Biotechnology*, 102(2):165–175, Apr. 2003. doi: 10.1016/S0168-1656(03)00018-X.
- S. Shen, G. C. Premier, A. Guwy, and R. Dinsdale. Bifurcation and stability analysis of an anaerobic digestion model. *Nonlinear Dyn*, 48(4):391–408, Aug. 2006. doi: 10.1007/s11071-006-9093-1.
- H. Siegrist, D. Vogt, J. L. Garcia-Heras, and W. Gujer. Mathematical model for meso- and thermophilic anaerobic sewage sludge digestion. *Environmental science & technology*, 36(5):1113–23, Mar. 2002. doi: 10.1021/es010139p.
- I. Simeonov. Modelling and control of anaerobic digestion of organic waste. *Chem Biochem Eng Q*, 8(2):45–52, 1994.
- I. Simeonov and I. Queinnec. Linearizing control of the anaerobic digestion with addition of acetate (control of the anaerobic digestion). *Control Engineering Practice*, 14(7):799–810, July 2006. doi: 10.1016/j.conengprac.2005.04.011.
- I. Simeonov and S. Stoyanov. Modelling and Dynamic Compensator Control of the Anaerobic Digestion of Organic Wastes. *Chem Biochem Eng Q*, 17(4):285–292, 2003.
- I. Simeonov and S. Stoyanov. Modelling and Extremum Seeking Control of a Cascade of Two Anaerobic Bioreactors. *International Journal Bioautomation*, 15(1):13–24, 2011.
- I. Simeonov, N. Noykova, and M. Gyllenberg. Identification and Extremum Seeking Control of the Anaerobic Digestion of Organic Wastes. *Cybernetics and Information technologies*, 7(2):73–84, 2007.
- D. Simon. *Optimal State Estimation: Kalman, H Infinity, and Nonlinear Approaches*. Wiley-Interscience, 2006.
- I. V. Skiadas, H. N. Gavala, J. E. Schmidt, and B. K. Ahring. Anaerobic granular sludge and biofilm reactors. *Adv Biochem Eng Biot*, 82:35–67, Jan. 2003.
- I. Y. Smets, J. V. Haegebaert, R. Carrette, and J. F. Van Impe. Linearization of the activated sludge model ASM1 for fast and reliable predictions. *Water research*, 37(8):1831–51, Apr. 2003. doi: 10.1016/S0043-1354(02)00580-8.
- H. Spanjers and J. van Lier. Instrumentation in anaerobic treatment: research and practice. *Water Sci Technol*, 53(4-5):63–76, Mar. 2006. doi: 10.2166/wst.2006.111.
- K. Stamatelatou, G. Lyberatos, C. Tsiligiannis, S. Pavlou, P. Pullammanappallil, and S. A. Svoronos. Optimal and suboptimal control of anaerobic digesters. *Environ Model Assess*, 2(4):355–363, 1997. doi: 10.1023/A:1019034032664.
- Statistics Netherlands. Renewable energy in the Netherlands 2011. Technical report, Centraal Bureau voor de Statistiek, The Hague/Heerlen, 2012.
- J. P. Steyer, D. Rolland, J. C. Bouvier, and R. Moletta. Hybrid fuzzy neural network for diagnosis — application to the anaerobic treatment of wine distillery wastewater in a fluidized bed reactor. *Water Sci Technol*, 36(6-7):209–217, 1997. doi: 10.1016/S0273-1223(97)00525-8.
- J.-P. Steyer, P. Buffière, D. Rolland, and R. Moletta. Advanced control of anaerobic digestion processes through disturbances monitoring. *Water Research*, 33(9):2059–2068, June 1999. doi: 10.1016/S0043-1354(98)00430-8.

- J. P. Steyer, O. Bernard, D. Batstone, and I. Angelidaki. Lessons learnt from 15 years of ICA in anaerobic digesters. *Water Sci Technol*, 53(4-5):25–33, Mar. 2006. doi: 10.2166/wst.2006.107.
- S. Strömberg, M. O. Possfelt, and J. Liu. Computer simulation of control strategies for optimal anaerobic digestion. *Water Sci Technol*, 67(3):594–603, Jan. 2012. doi: 10.2166/wst.2012.603.
- A. Stuhlsatz, J. Lippel, and T. Zielke. Discriminative feature extraction with Deep Neural Networks. In *The 2010 20th International Joint Conference on Neural Networks (IJCNN)*, volume 0, pages 1–8, Barcelona, July 2010a. IEEE. doi: 10.1109/IJCNN.2010.5596329.
- A. Stuhlsatz, J. Lippel, and T. Zielke. Feature Extraction for Simple Classification. In *2010 20th International Conference on Pattern Recognition*, number x, pages 1525–1528, Istanbul, Aug. 2010b. IEEE. doi: 10.1109/ICPR.2010.377.
- A. Stuhlsatz, J. Lippel, and T. Zielke. Feature Extraction With Deep Neural Networks by a Generalized Discriminant Analysis. *IEEE Transactions on Neural Networks and Learning Systems*, 23(4):596–608, Apr. 2012. doi: 10.1109/TNNLS.2012.2183645.
- H. O. Tabrizi, G. Amoabediny, B. Moshiri, A. Adhami, M. P. H. Abbas, and E. Imenipour. Sliding mode control of an anaerobic upflow fixed bed bioreactor. *J Biotechnol*, 150(null):227–228, Nov. 2010. doi: 10.1016/j.jbiotec.2010.09.065.
- B. Tartakovsky, E. Morel, J. P. Steyer, and S. R. Guiot. Application of a variable structure model in observation and control of an anaerobic digester. *Biotechnology progress*, 18(4):898–903, 2002. doi: 10.1021/bp010142c.
- B. Tartakovsky, E. Morel, and S. R. Guiot. Application of a VSM-Based Process Control to a Bench-Scale Anaerobic Digester. *Industrial & Engineering Chemistry Research*, 44(1):106–113, Jan. 2005. doi: 10.1021/ie030799y.
- D. Theilliol, J.-C. Ponsart, J. Harmand, C. Join, and P. Gras. On-line estimation of unmeasured inputs for anaerobic wastewater treatment processes. *Control Eng Pract*, 11(9):1007–1019, Sept. 2003. doi: 10.1016/S0967-0661(02)00230-7.
- X. Tian, P. Wang, D. Huang, and S. Chen. Offset-free multistep nonlinear model predictive control under plant-model mismatch. *International Journal of Adaptive Control and Signal Processing*, pages n/a–n/a, Nov. 2012. doi: 10.1002/acs.2367.
- P. A. Tipler and G. Mosca. *Physik: für Wissenschaftler und Ingenieure (German Edition)*. Spektrum Akademischer Verlag, 2nd edition, 2007.
- M. C. Tomei, C. M. Braguglia, G. Cento, and G. Mininni. Modeling of Anaerobic Digestion of Sludge. *Critical Reviews in Environmental Science and Technology*, 39(12):1003–1051, Nov. 2009. doi: 10.1080/10643380801977818.
- H. Trautmann, T. Wagner, and D. Brockhoff. R2-EMOA : Focused Multiobjective Search Using R2-Indicator-Based Selection. In *Learning and Intelligent Optimization Conference*, 2013.
- R. Tschepetzki and M. Ogurek. SIMBA, 2010.
- M. Türk. Rohrleitungstransport von Flüssigmist - Druckverlustberechnung, Stoffdaten, Tabellen, Programmbeschreibung. Technical report, Institut für Agrartechnik Bornim e.V., Potsdam, 1994.

- D. Urrego-Patarroyo, E. Sanchez, S. Carlos-Hernandez, and J. F. Beteau. Recurrent Neural Networks Biomass Observer for Anaerobic Processes. In *2008 IEEE International Symposium on Intelligent Control*, pages 183–188. IEEE, Sept. 2008. doi: 10.1109/ISIC.2008.4635946.
- J. J. Valera García, V. Gómez Garay, E. Irigoyen Gordo, F. Artaza Fano, and M. Larrea Sukia. Intelligent Multi-Objective Nonlinear Model Predictive Control (iMO-NMPC): Towards the 'on-line' optimization of highly complex control problems. *Expert Syst Appl*, 39(7):6527–6540, June 2012. doi: 10.1016/j.eswa.2011.12.052.
- P. J. Van Soest, J. B. Robertson, and B. A. Lewis. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J Dairy Sci*, 74(10):3583–97, Oct. 1991. doi: 10.3168/jds.S0022-0302(91)78551-2.
- VDI. *VDI 4630 - Vergärung organischer Stoffe*. Verein deutscher Ingenieure, Düsseldorf, april 2006 edition, 2006.
- V. D. L. U.-u. F. VDLUFA. *Methodenbuch. Band III. Die chemische Untersuchung von Futtermitteln*. VDLUFA-Verlag, Darmstadt, inkl. 4. e edition, 1997.
- A. K. Venkatesan. *Optimization of Substrate Feed in a Biogas Plant Using Non-linear Model Predictive Control*. Master thesis, Cologne University of Applied Sciences, 2012.
- J. von Sachs, U. Meyer, P. Rys, and H. Feitkenhauer. New approach to control the methanogenic reactor of a two-phase anaerobic digestion system. *Water research*, 37(5):973–82, Mar. 2003.
- E. Voß, D. Weichgrebe, and K.-H. Rosenwinkel. FOS/TAC: Herleitung, Methodik, Anwendung und Aussagekraft. In *Internationale Wissenschaftstagung Biogas Science 2009 Band 3*, pages 675–682, Freising, 2009. Bayerische Landesanstalt für Landwirtschaft.
- C. Waewsak, A. Nopharatana, and P. Chaiprasert. Neural-fuzzy control system application for monitoring process response and control of anaerobic hybrid reactor in wastewater treatment and biogas production. *Journal of Environmental Sciences*, 22(12):1883–1890, Dec. 2010. doi: 10.1016/S1001-0742(09)60334-X.
- T. Wagner and H. Trautmann. Integration of Preferences in Hypervolume-Based Multiobjective Evolutionary Algorithms by Means of Desirability Functions. *IEEE T Evolut Comput*, 14(5):688–701, Oct. 2010. doi: 10.1109/TEVC.2010.2058119.
- T. Wagner, N. Beume, and B. Naujoks. Pareto-, aggregation-, and indicator-based methods in many-objective optimization. *Lecture Notes in Computer Science - Evolutionary Multi-Criterion Optimization*, 4403(September):742–756, 2007. doi: 10.1007/978-3-540-70928-2_56.
- T. Wagner, M. Emmerich, A. Deutz, and W. Ponweiser. On expected-improvement criteria for model-based multi-objective optimization. *Lecture Notes in Computer Science - Parallel Problem Solving from Nature - PPSN XI*, 6238:718–727, 2010. doi: 10.1007/978-3-642-15844-5_72.
- H. Wang, B. Kalchev, Y. Tian, I. Simeonov, N. Christov, and C. Vasseur. Composed Adaptive Control for a second-order nonlinear model of a biotechnological process. In *2011 19th Mediterranean Conference on Control & Automation (MED)*, pages 1140–1143, Corfu, June 2011. IEEE. doi: 10.1109/MED.2011.5983138.

- H. Wang, B. Kalchev, Y. Tian, I. Simeonov, and N. Christov. Modelling and Composed Recursive Model Free Control for the Anaerobic Digestion Process. *Advances in Intelligent Control Systems and Computer Science - Advances in Intelligent Systems and Computing*, 187:265–278, 2013. doi: 10.1007/978-3-642-32548-9_19.
- P. Weiland. Biomass Digestion in Agriculture: A Successful Pathway for the Energy Production and Waste Treatment in Germany. *Engineering in Life Sciences*, 6(3): 302–309, June 2006. doi: 10.1002/elsc.200620128.
- P. Weiland. Biogas production: current state and perspectives. *Applied microbiology and biotechnology*, 85(4):849–60, Jan. 2010. doi: 10.1007/s00253-009-2246-7.
- F. Weiß bach and C. Strubelt. Die Korrektur des Trockensubstanzgehaltes von Grassilagen als Substrat für Biogasanlagen. *Landtechnik*, 63(4):210–212, 2008a.
- F. Weiß bach and C. Strubelt. Die Korrektur des Trockensubstanzgehaltes von Maissilagen als Substrat für Biogasanlagen. *Landtechnik*, 63(2):2–4, 2008b.
- F. Weiß bach and C. Strubelt. Die Korrektur des Trockensubstanzgehaltes von Zuckerrübensilagen als Substrat für Biogasanlagen. *Landtechnik*, 63(6):354–356, 2008c.
- A. Wenzel. Evolutionary Algorithm Application for Parameter Estimation of the Anaerobic Digestion Model No. 1. In *2008 IEEE International Conference on Computational Cybernetics*, number 1, pages 101–105. IEEE, Nov. 2008. doi: 10.1109/ICCCYB.2008.4721387.
- B. Wett, A. Eladawy, and M. Ogurek. Description of nitrogen incorporation and release in ADM1. *Water Sci Technol*, 54(4):67–76, Jan. 2006.
- T. Whitmore, D. Lloyd, G. Jones, and T. Williams. Hydrogen-dependent control of the continuous anaerobic digestion process. *Applied Microbiology and Biotechnology*, 26(4):383–388, July 1987. doi: 10.1007/BF00256675.
- T. N. Whitmore and D. Lloyd. Mass spectrometric control of the thermophilic anaerobic digestion process based on levels of dissolved hydrogen. *Biotechnology Letters*, 8(3):203–208, Mar. 1986. doi: 10.1007/BF01029381.
- M. Wichern, M. Lübken, K. Koch, T. Gehring, H. Horn, K. Fischer, M. Schlattman, and A. Gronauer. Eignung des Anaerobic Digestion Model No. 1 (ADM 1) zur Prozesssteuerung landwirtschaftlicher Biogasanlagen. In *Gülzower Fachgespräche: Band 27 Messen, Steuern, Regeln bei der Biogaserzeugung*, pages 172–194, Gülzow, 2007. FNR.
- M. Wichern, M. Lübken, H. Horn, M. Schlattmann, and A. Gronauer. Investigations and mathematical simulation on decentralized anaerobic treatment of agricultural substrate from livestock farming. *Water Sci Technol*, 58(1):67–72, Jan. 2008. doi: 10.2166/wst.2008.332.
- M. Wichern, T. Gehring, K. Fischer, D. Andrade, M. Lübken, K. Koch, A. Gronauer, and H. Horn. Monofermentation of grass silage under mesophilic conditions: measurements and mathematical modeling with ADM 1. *Bioresource technology*, 100(4):1675–81, Feb. 2009. doi: 10.1016/j.biortech.2008.09.030.
- J. Wiese and R. König. From a black-box to a glass-box system: the attempt towards a plant-wide automation concept for full-scale biogas plants. *Water Sci Technol*, 60(2):321–7, Jan. 2009. doi: 10.2166/wst.2009.337.

- S. Wilcox, D. Hawkes, F. Hawkes, and A. Guwy. A neural network, based on bicarbonate monitoring, to control anaerobic digestion. *Water Research*, 29(6): 1465–1470, June 1995. doi: 10.1016/0043-1354(94)00314-W.
- C. Wolf. *Simulation, optimization and instrumentation of agricultural biogas plants*. Doctoral dissertation, NUI Maynooth, 2013.
- C. Wolf, S. McLoone, and M. Bongards. Biogas Plant Control and Optimization Using Computational Intelligence Methods (Biogasanlagenregelung und -optimierung mit Computational Intelligence Methoden). *at - Automatisierungstechnik*, 57(12): 638–649, Dec. 2009. doi: 10.1524/auto.2009.0809.
- A. Wolfsberger. *Modelling and Control of the Anaerobic Digestion of Energy Crops*. Dissertation, Universität für Bodenkultur, 2008.
- B. Wu and E. L. Bibeau. Development of 3-D anaerobic digester heat transfer model for cold weather applications. *Transactions of the ASABE*, 49(3):749–757, 2006.
- L. Würth, R. Hannemann, and W. Marquardt. A two-layer architecture for economically optimal process control and operation. *Journal of Process Control*, 21(3):311–321, Mar. 2011. doi: 10.1016/j.jprocont.2010.12.008.
- S. Yordanova, R. Petrova, and V. Mladenov. Neuro-Fuzzy Control for Anaerobic Wastewater Treatment. *WSEAS Transactions on Systems*, 2(3):724–729, 2004.
- U. Zaher, R. Li, U. Jeppsson, J.-P. Steyer, and S. Chen. GISCOD: general integrated solid waste co-digestion model. *Water research*, 43(10):2717–27, June 2009. doi: 10.1016/j.watres.2009.03.018.
- U. E.-S. Zaher. *Modelling and Monitoring the Anaerobic Digestion Process in view of Optimisation and smooth Operation of WWTP's*. PhD thesis, Universiteit Gent, 2005.
- H. Zhou, H. Li, and F. Wang. Anaerobic digestion of different organic wastes for biogas production and its operational control performed by the modified ADM1. *J Environ Sci Heal A*, 47(1):84–92, Jan. 2012. doi: 10.1080/10934529.2012.629585.
- J. Ziegenhirt, T. Bartz-Beielstein, O. Flasch, W. Konen, and M. Zaefferer. Optimization of biogas production with computational intelligence a comparative study. In *IEEE Congress on Evolutionary Computation*, pages 1–8. IEEE, July 2010. doi: 10.1109/CEC.2010.5586509.
- E. Zitzler and L. Thiele. Multiobjective optimization using evolutionary algorithms—A comparative case study. *Lecture Notes in Computer Science - Parallel Problem Solving from Nature—PPSN V*, 1498(September):292–301, 1998. doi: 10.1007/BFb0056872.
- E. Zitzler, M. Laumanns, and L. Thiele. SPEA2: Improving the strength Pareto evolutionary algorithm. Technical report, 2001.
- E. Zitzler, L. Thiele, M. Laumanns, C. Fonseca, and V. da Fonseca. Performance assessment of multiobjective optimizers: an analysis and review. *IEEE T Evolut Comput*, 7(2):117–132, Apr. 2003. doi: 10.1109/TEVC.2003.810758.