Bioenergy recovery from sewage sludge in wastewater treatment plant : Machine learning and heterogeneous datasets

Anaerobic Digestion II, Room 1 Session XIII

16:30 pm – 16:45 pm , 16 June 2022

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Energy and Environmental Sustainability Solutions for Megacities
A joint programme by Shanghai Jiao Tong University and National University of Singapore

Outline

- Background & Challenges
- Approach & Methodology
- Findings & Discussions
- Summary

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Energy and Environmental Sustainability Solutions for Megacities (E2S2-CREATE)

E2S2-CREATE:

To understand and model for policy formulation and technology development, while reaching down from the city-wide model and developing deeper into the implementations at solving specific urban megacity challenges.

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E2S2-CREATE Directors:

Prof. Yinghong PENG, Shanghai Jiao Tong University (SJTU)
Prof. Yen Wah TONG, National University of Singapore (NUS)

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Background

- Urban waste management
  - High disposal costs and carbon emissions
  - Circular economy and a net-zero green future
- Urban Constraints and Challenges
  - Fast-changing needs and complexity
  - Space, economic factors, etc.
- <u>Bioenergy recovery from recalcitrant biomass</u>
  - E.g. Sewage sludge, Agricultural waste, Food waste (sometimes)
  - Complex structure and barriers to the penetration of hydrolytic enzymes
  - Pretreatment needs (e.g. thermal, chemical, electric methods)
  - Enhanced destruction; Reduced digestate volume; Compact digester

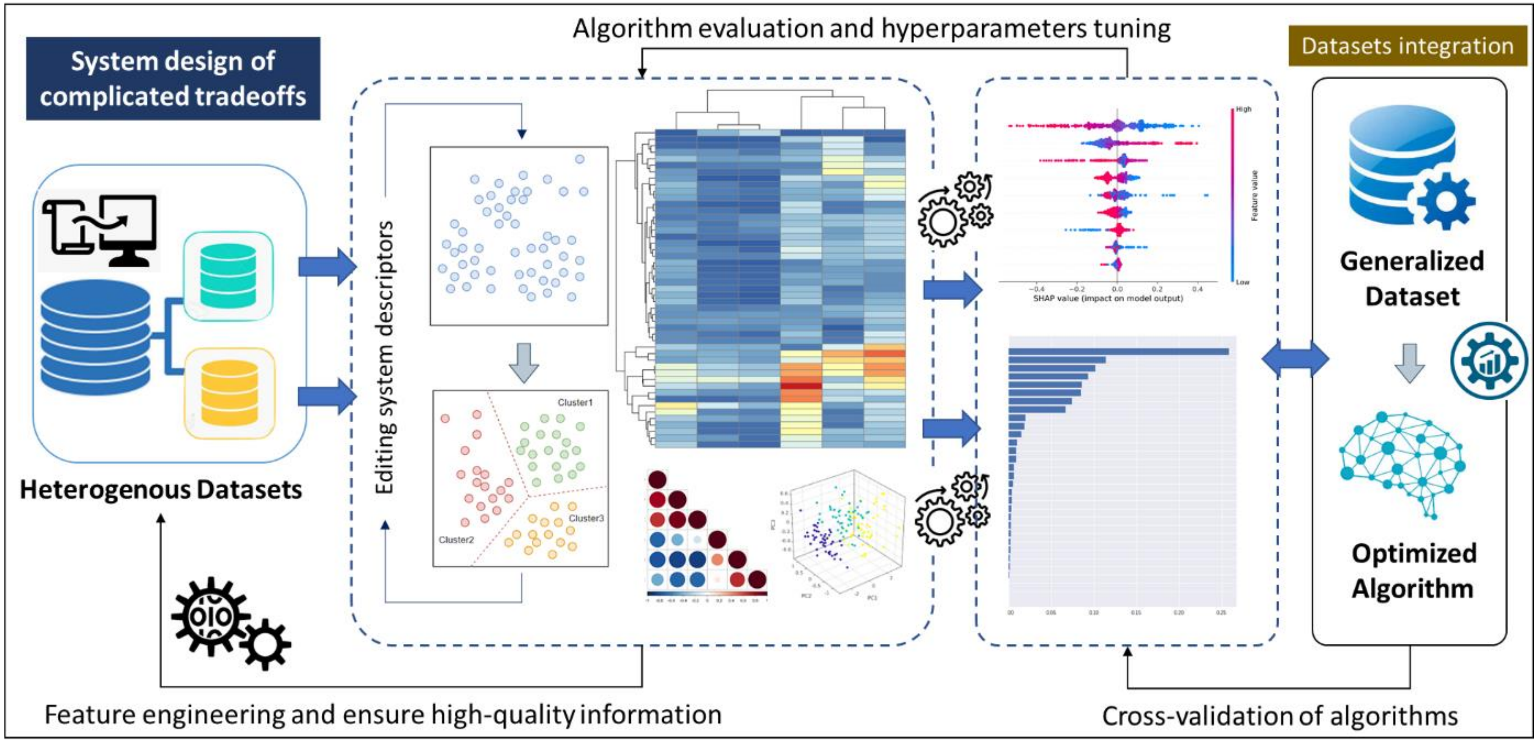
Challenges

- Technological constraints for system optimization
  - Slow experiments, labor intensive, and highly expensive
  - Tradeoffs with high-dimension of variables
  - Difficult to fully explore/ comprehend

- Conventional performance simulation
  - Time consuming; Unable to quickly handle increasing parameters
  - More confined to mechanistic derivation (e.g. ADM)

- A unified computational framework (to tackle prediction needs)
  - Artificial intelligence techniques in recent years; Fast-growing capacity
  - Multiple use of algorithms for compiling heterogenous datasets

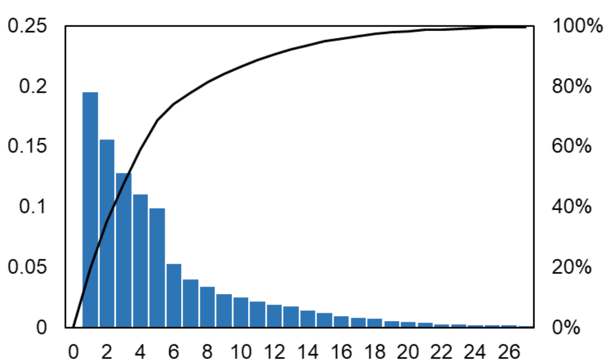
Approach & Methodology

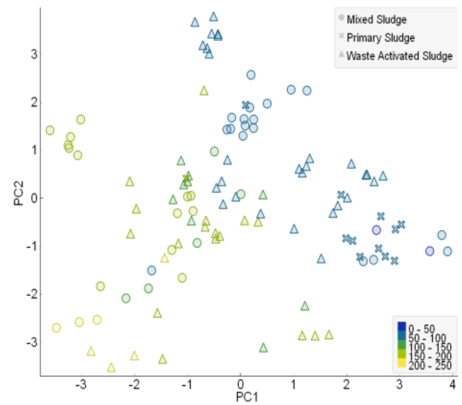


The experimental data were collected from publications from 1990 to 2021, and there is a total of 236 experimental references selected for the architectural computation.

Findings & Discussions

- Main difficulties





AD_VS_removal	-0.07833	-0.02451	0.196619	-0.03682	-0.02229
Type_Secondary_Sludge	-0.07678	0.042612	0.006286	-0.01586	-0.02507
Pretreatment_Temperature	-0.06618	-0.22009	0.535018	-0.1591	-0.05858
I_TN_after	-0.05388	-0.02363	0.060836	-0.03356	-0.01898
Pretreatment type=Ferrate + FNA	-0.03671	0.133421	-0.00303	0.015114	-0.09595
Chemical Species=K2FeO4 +FNA	-0.03671	0.133421	-0.00303	0.015114	-0.09595
AD_Temperature	-0.03172	0.039233	0.026966	0.161737	0.901393
Chemical Species=CaO2	-0.03003	0.001561	-0.02148	0.038327	-0.0088
Pretreatment_pH	-0.0252	-0.40318	0.274206	-0.34327	0.118492
Chemical Species=K2FeO4+KOH	-0.02352	0.012167	0.013781	0.002821	0.015155
Pretreatment_Duration	-0.01673	0.004901	-0.40769	-0.00734	0.161547
Pretreatment type=Alkali	-0.01247	-0.15805	0.073952	-0.16161	0.037584
I_SCOD_after	-0.00766	0.019144	0.075222	0.03747	0.174056
Pretreatment type=Alkali, 2 stage Acidogenic	-0.00677	-0.00903	0.002891	-0.00352	0.005123
I_VS/TS_after	-0.00653	-0.00576	-0.02064	0.021541	-0.00639
I_VS_after	-0.00614	-0.00402	-0.01615	0.023149	-0.00648
Reactor Type=Batch	-0.00279	0.009025	0.0046	0.025149	-0.00229
Chemical Species=NaOH	-0.00178	-0.21056	0.100774	-0.13034	0.01337
Chemical Species=KOH	-0.00071	-0.00488	0.007645	-0.00165	0.001909
Primary_Dosage	-0.00012	0.001054	0.001139	0.000813	0.000567
Chemical Species=Na2SO3	0.000695	0.038985	-0.01482	-0.01121	0.049614
Pretreatment type=Sulfite	0.000695	0.038985	-0.01482	-0.01121	0.049614
Pretreatment type=Ferrate	0.000828	0.001411	0.000233	-0.00425	0.005431
Chemical Species=K2FeO4	0.000828	0.001411	0.000233	-0.00425	0.005431
Reactor Type=Semi Continuous	0.002792	-0.00903	-0.0046	-0.02515	0.002295
I_TS_after	0.008254	0.038941	0.124072	0.023693	-0.00585
Chemical Species=Mixed Alkali	0.011337	0.003643	0.015427	-0.02338	-0.02543
TN_before	0.012384	-0.0312	-0.02166	-0.00794	-0.04306
Chemical Species=CaClO2	0.025476	0.030994	-0.0393	-0.05091	0.046503
SCOD_before	0.028995	-0.2342	0.004064	0.098317	0.149508
AD_control_biomethane	0.0404	-0.40142	-0.45113	-0.07892	-0.02577
Chemical Species=Nitrous Acid	0.05442	-0.00674	-0.05923	0.165478	-0.00181
Pretreatment type=Acid	0.05442	-0.00674	-0.05923	0.165478	-0.00181
AD_pretreatment_biomethane	0.057247	-0.38903	-0.38331	-0.20692	-0.08543
Type_Sludge_Mixture	0.076782	-0.04261	-0.00629	0.015857	0.025073
VS/TS before	0.087726	-0.395	0.065531	0.082016	0.118826
TS_before	0.326067	-0.16971	0.114756	0.474176	-0.1028
VS_before	0.34062	-0.24285	0.112754	0.480299	-0.10467
AD_Pretreated_Duration	0.487635	0.127419	0.012606	-0.30699	0.088436
AD_Control_Duration	0.488059	0.124814	0.0122	-0.30783	0.086278
HRT/SRT	0.499658	0.165422	0.019729	-0.10075	-0.01299
components	PC1	PC2	PC3	PC4	PC5
variance	0.20843	0.159289	0.145843	0.111938	0.069103

- Final prediction performance

Scope	XGBoost			
	Prediction accuracy	Probabilities of advantaged prediction against others		
	R^2	kNN	SVM	NN
Thermal dataset	0.929	0.901	0.854	0.810
Chemical dataset	0.903	0.953	0.972	0.939
Generic algorithm	0.878	0.969	0.908	0.992

Summary

- A computational approach
  - to deal with prediction complexity & accuracy
  - to encounter dynamic changes in urban environments
- Experiment-derived simulation with proven accuracy
- A generic algorithm with transferable and growth potentials
- Next: Integration with other artificial intelligence techniques
  - E.g. Packaged programming for automated data analytics

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Thank you!

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