Applying decision intelligence to an industrial filtration system

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October 10, 2023

Critical Systems Thinking [Jackson, 2019]

Designed to

1. incorporate progress made in systems thinking over many decades
2. avoid the biases of looking through just one lens
3. leverage other approaches, such as decision intelligence, strategic options, system dynamics, etc

Critical Systems Thinking is a meta-framework for choosing the best combination of approaches for a given scenario

Decision Intelligence [Pratt and Malcolm, 2023]

Designed to

1. enhance decision making in mission-centric scenarios
2. avoid common pitfalls of group-based problem solving
3. optimize use of decision assets (data mining, simulations, etc)

We sketch an end-to-end application of Decision Intelligence, showing how it can empower decision makers by leveraging decision assets as effectively as possible.

Objective statement for a hypothetical shipping company

“How can we improve the efficiency of our contaminant filtering systems?”

We frame the objective more precisely by answering questions such as...

1. who has the authority to make the decisions?
2. who has responsibility for the outcomes?
3. what are the hard constraints?

Brainstorming outcomes

Putting ourselves in the decision maker's position, we could try to...

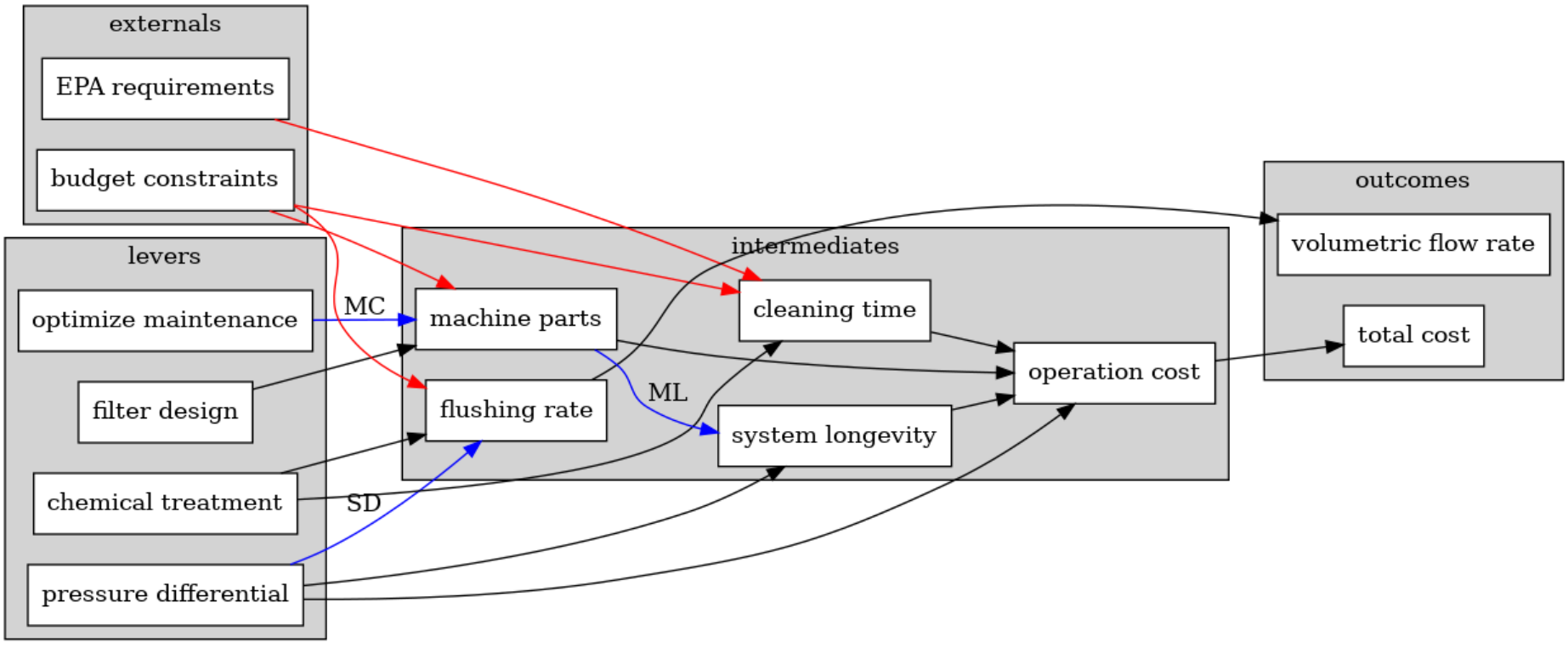
1. reduce total cost of running the systems
2. increase the volumetric flow rate of purified fluid

Brainstorming actions

Actions that might get us to those goals:

1. use different filter designs
2. optimize maintenance
3. purge filters with chemical treatments
4. increase pressure differential to eject more biomass

Causal decision diagram

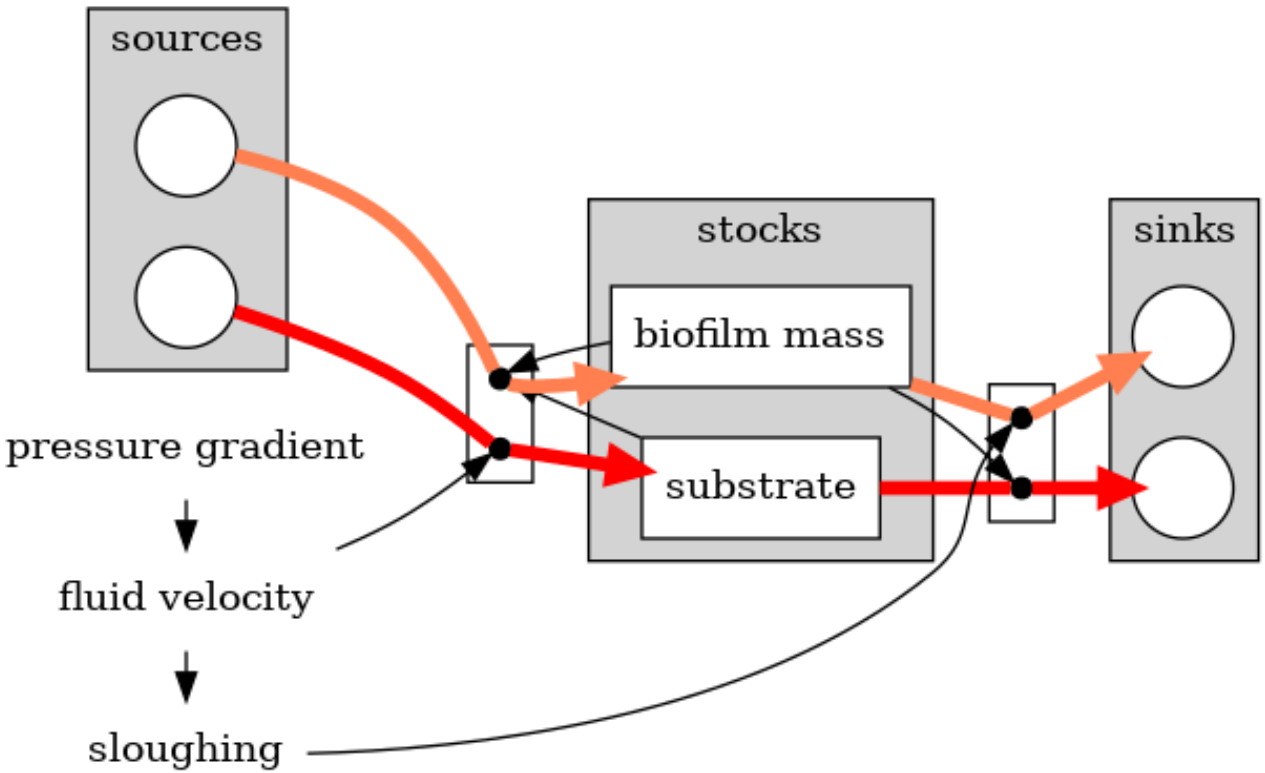


Monte Carlo simulations

part_type	prob_fail	loss_low	loss_high	mu	sigma	avg_loss
A	0.27	100	500	5.409889	0.804719	312.254137
B	0.20	200	800	5.991465	0.693147	508.406997
C	0.10	50	600	5.154476	1.242453	364.343198
D	0.40	300	500	5.959195	0.255413	399.823581

part_type	A	B	C	D
0	133.138376	586.580191	250.750436	377.407511
1	314.436230	279.469400	114.405700	362.264175
2	635.124213	1104.641780	64.635782	379.896570
3	407.367765	242.583823	923.240703	413.527680
4	210.812443	195.395831	84.716073	432.981676
...	...	...	...	...
9995	719.786273	598.075628	34.988016	256.209784
9996	81.421259	302.370980	554.909411	381.321068
9997	55.662005	187.528988	1608.923678	306.192447
9998	157.423867	374.896988	198.887214	461.879103
9999	34.294490	625.370196	1077.561133	577.357937

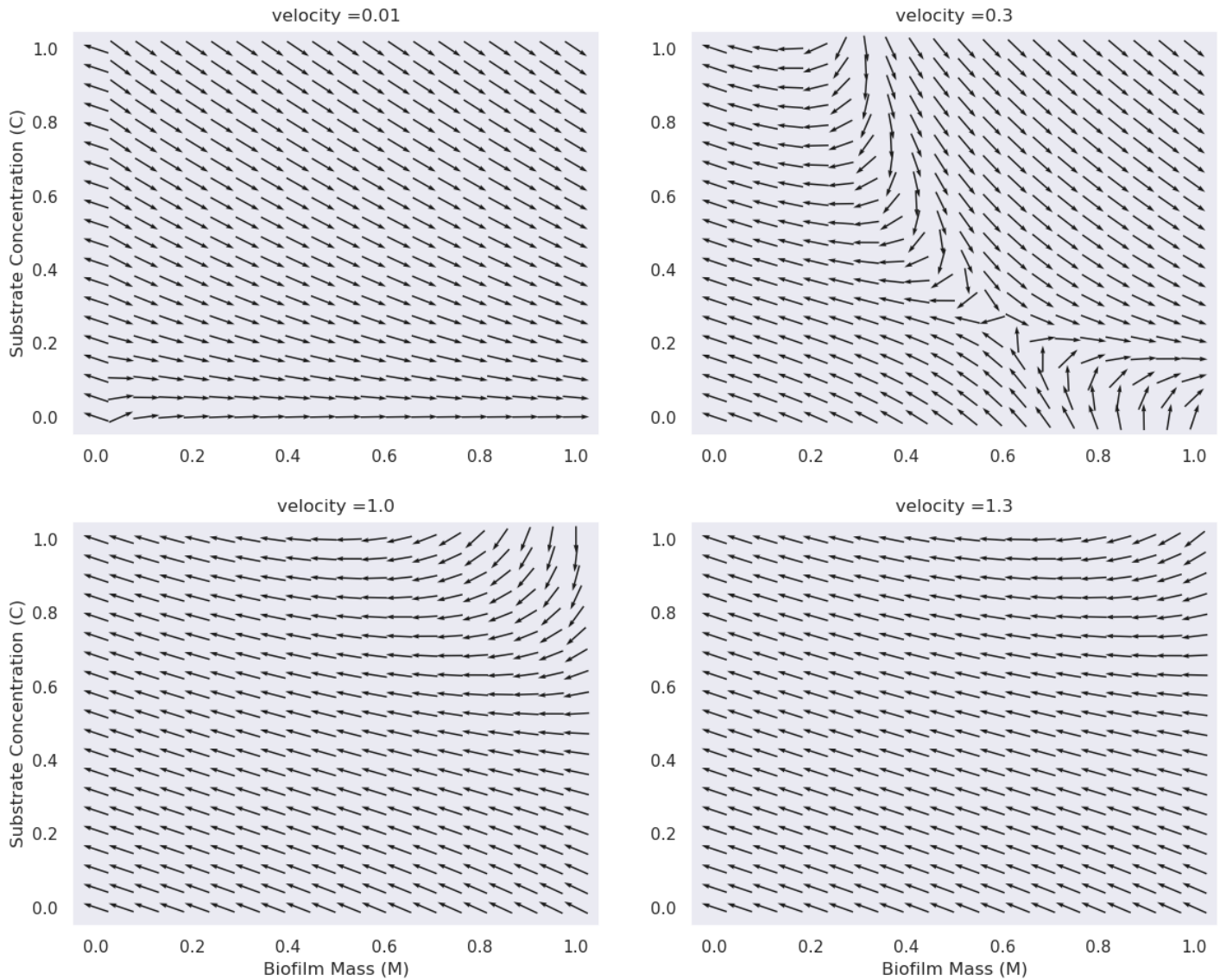
System dynamics



$$\dot{M} = \alpha M + \beta CM - \gamma V$$

$$\dot{C} = \delta V - \mu MC$$

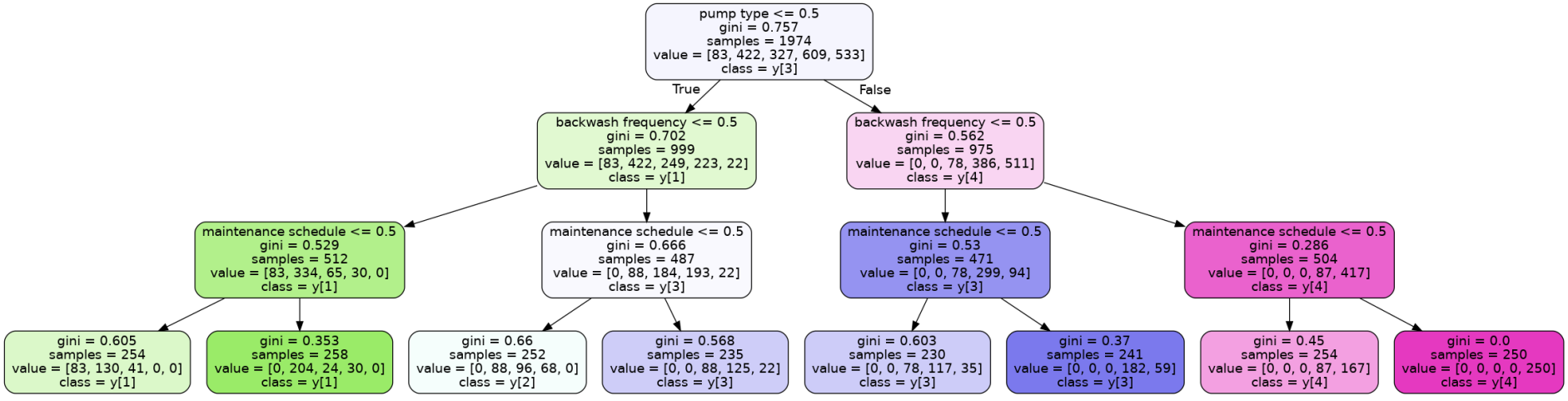
System vector field



Sample machine parts/maintenance data

pump type	filter type	maintenance schedule	...	longevity
1	1	0	...	5
0	1	1	...	2
1	0	0	...	5

Decision tree classifier



How well do the models do?

Both the decision tree and the neural net perform at around 64% accuracy, with similar confusion matrices:

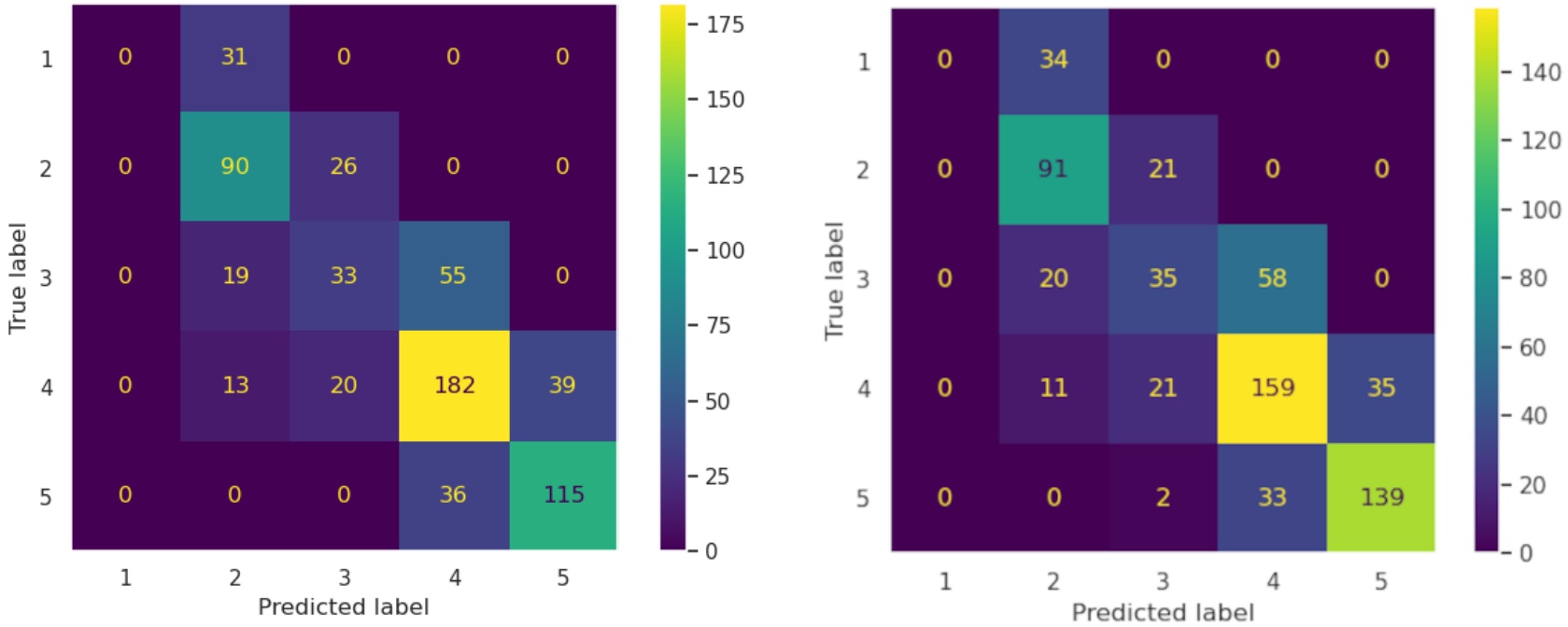


Figure: Confusion matrices for decision tree (left) and neural net (right) classifiers.

Summary

- Critical systems thinking is a general framework for systems thinking that encourages tailoring other approaches
- On of those of sub-frameworks, Decision Intelligence (DI), is an especially powerful approach for mission-centric problem-solving
- Using DI, we can create a causal decision diagram (CDD) as the basis of a decision model
- Machine learning models and other assets support the links in the CDD, which can be converted into a “digital twin” if the benefits of doing so outweigh costs
- We can use the resulting decision model as a collaborative and iterative approach for making complex, goal-directed decisions

References

MC Jacson (2019)
Critical Systems Thinking and the management of complexity
Wiley

LY Pratt and NE Malcom (2023)
The Decision Intelligence handbook: practical steps for evidence-based decisions in a complex world
O'Reilly

The End

Questions? Comments?