Applying decision intelligence to an industrial filtration system

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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...

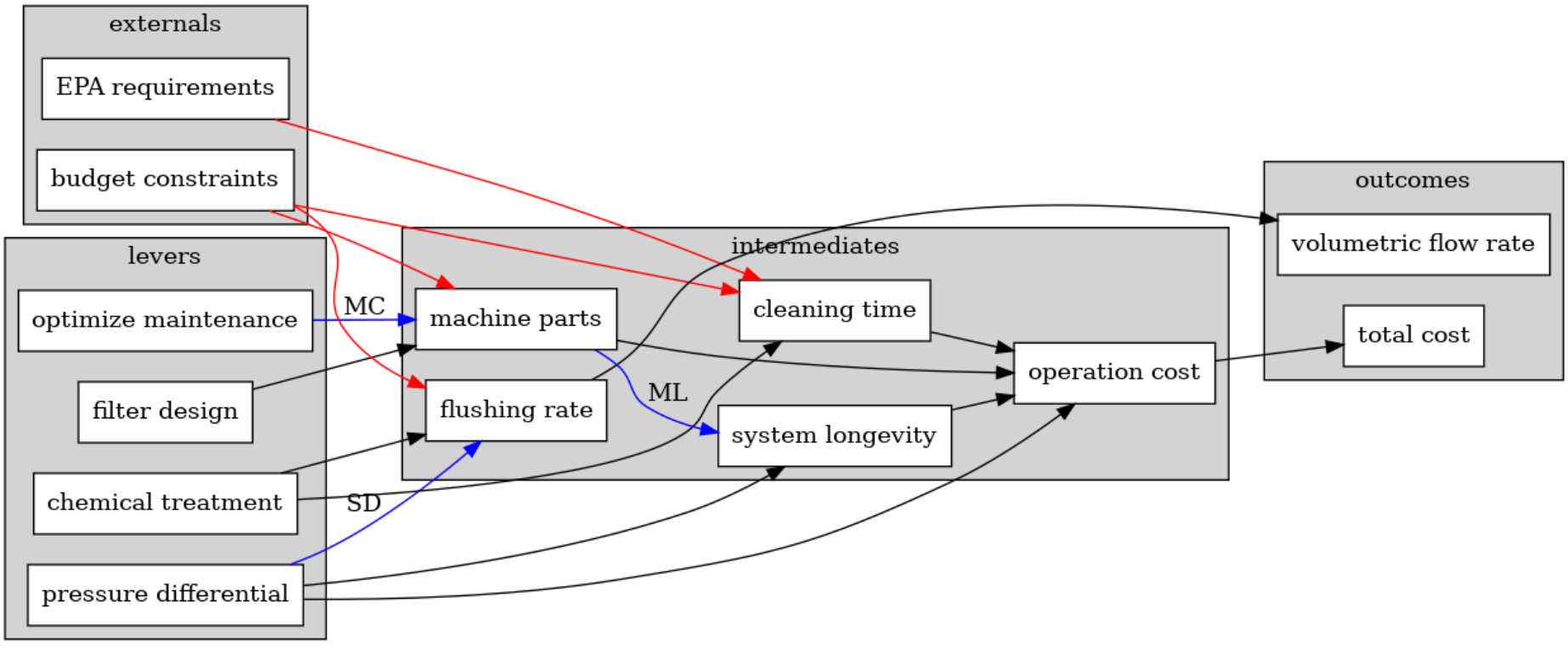
1. reduce total cost of running the systems
2. increase the volumetric flow rate of purified fluid

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
A	0.27	100	500
B	0.20	200	800
C	0.10	50	600
D	0.40	300	500

part_type	A	B	...	A_plus_B	C_plus_D
0	1024.856091	251.417453	...	326.994635	226.825827
1	313.847248	161.051366	...	116.949030	195.322013
2	507.122021	581.190310	...	253.161008	169.537294
3	101.233384	545.139549	...	136.360923	264.051652
4	87.675602	1160.300571	...	255.732527	112.611886
...	...	...	...	...	...
9995	306.794925	953.035974	...	273.441825	274.480277
9996	478.986427	925.981179	...	314.522571	148.092691
9997	126.010658	202.436750	...	74.510227	135.448055
9998	269.310082	132.723686	...	99.258459	159.445170
9999	169.030283	852.756567	...	216.189490	114.617479

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avg expected yearly loss from A plus B: 185.7
avg expected yearly loss from C plus D: 196.43
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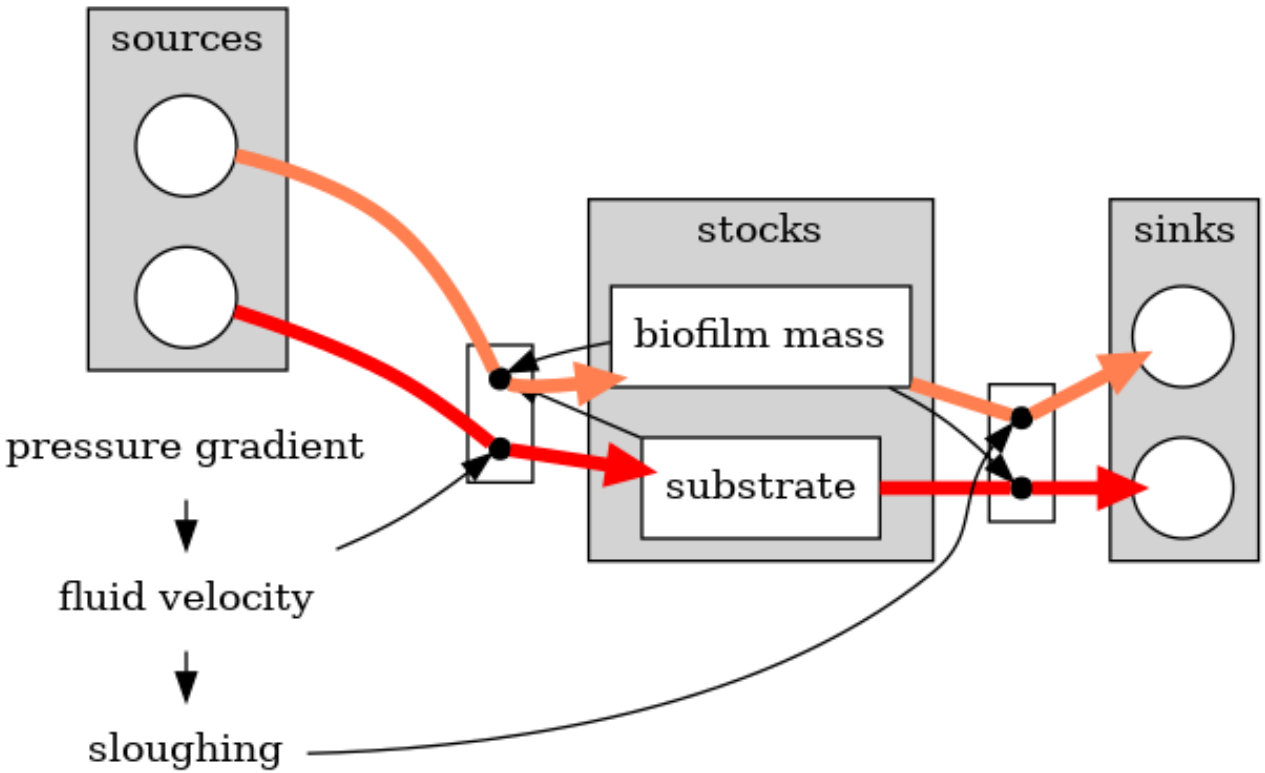
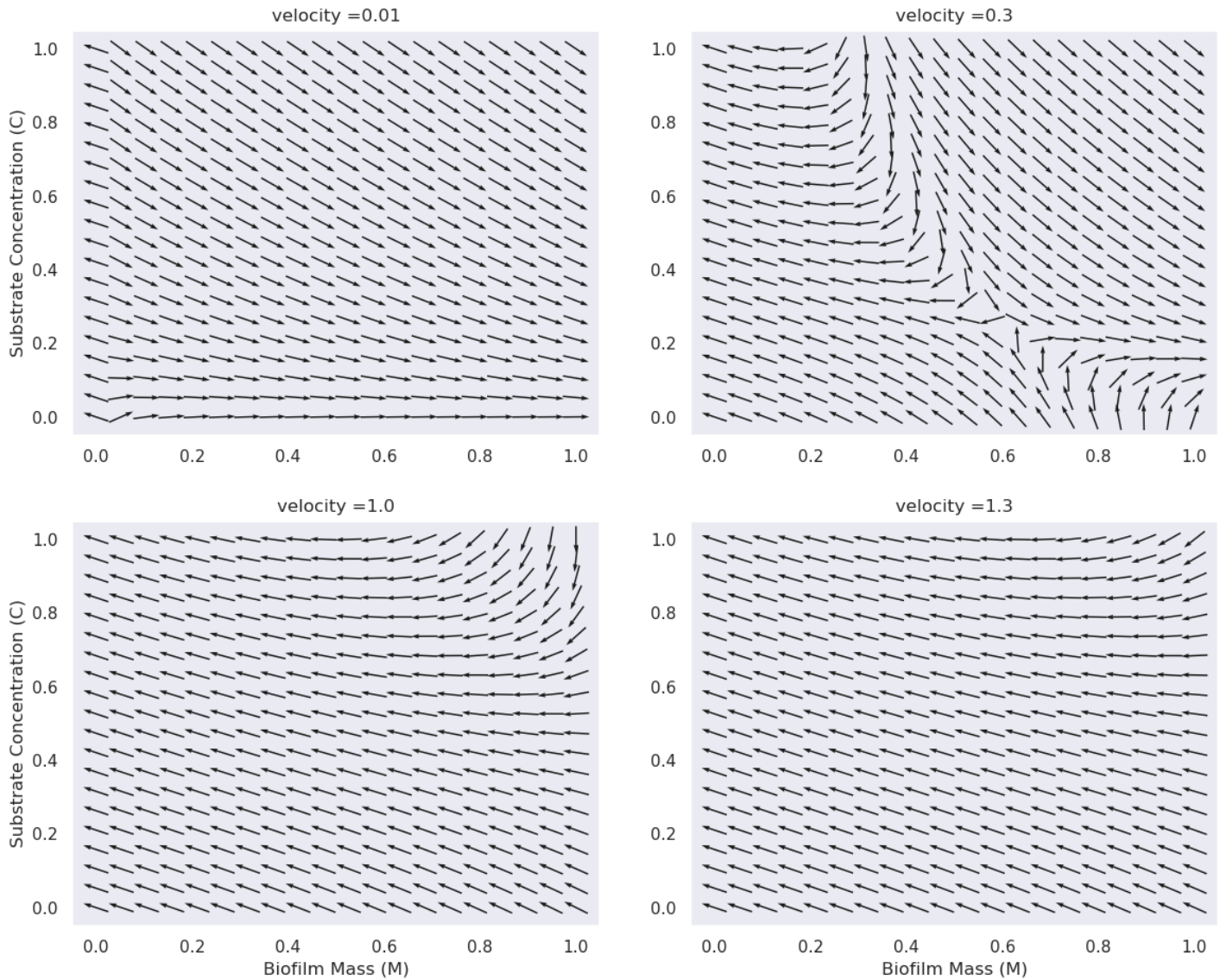
System dynamics



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

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

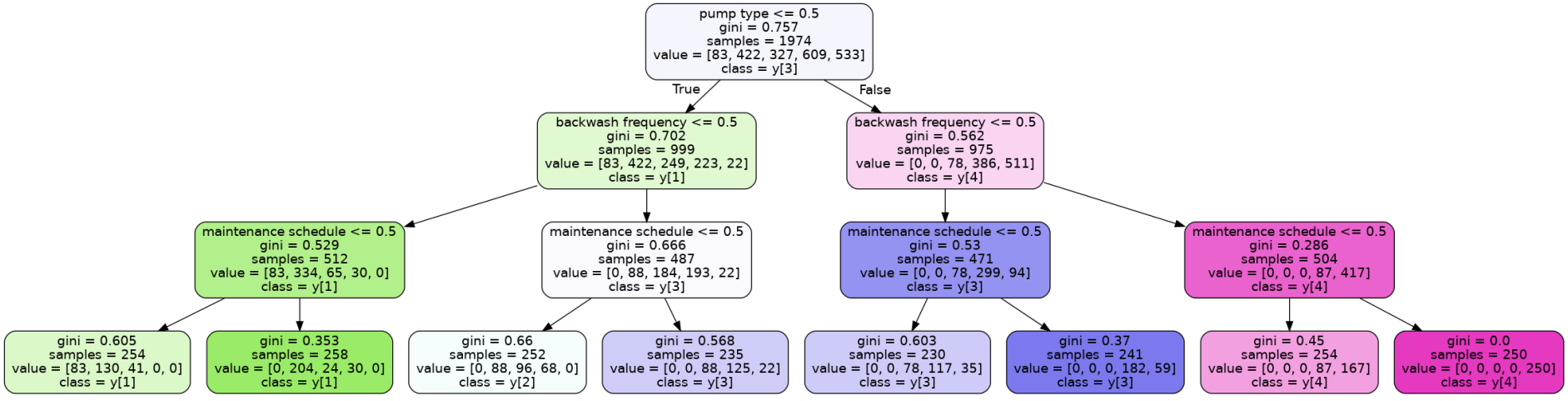
System vector field



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:

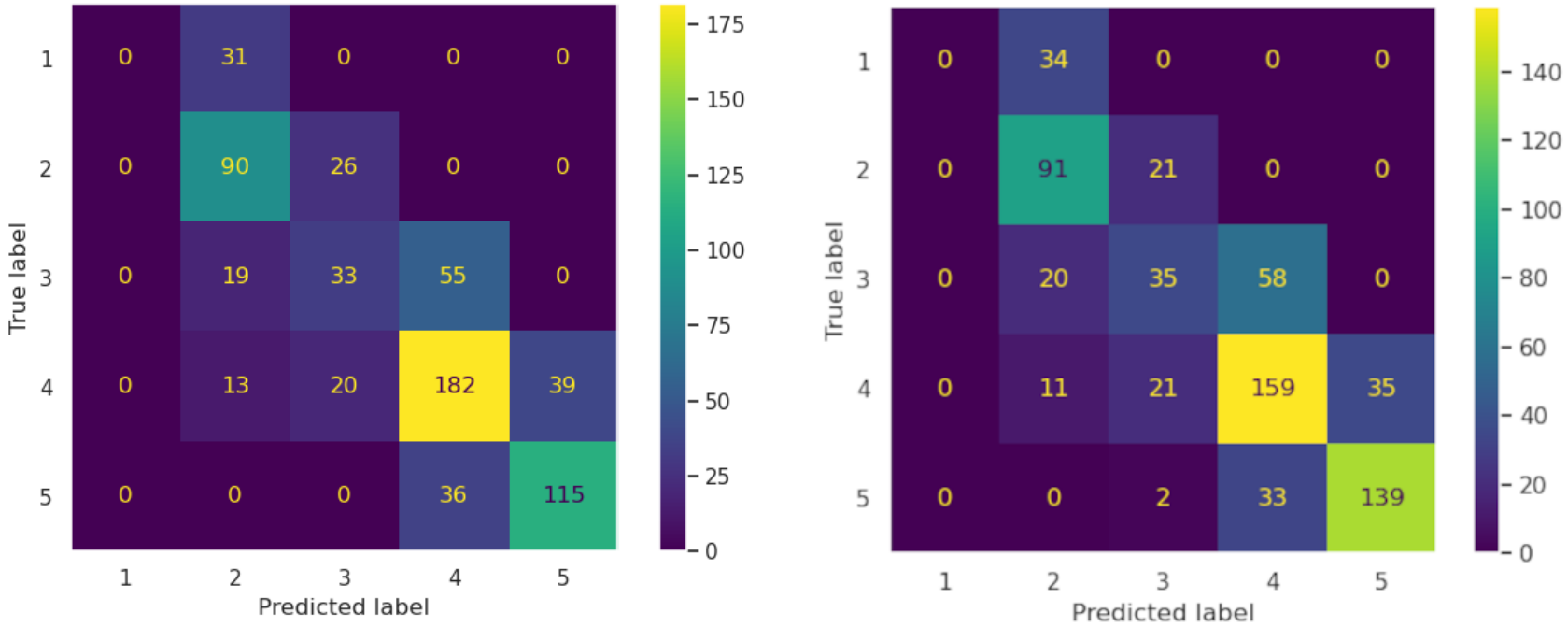


Figure: Confusion matrices for decision tree (left) and neural net (right) classifiers.

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?