Spur

(Simulation for Planning and Understanding Railways)

A Modular, Data-Driven Mesoscopic Simulator for Stochastic Railway Networks

Transit Analytics Lab

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https://github.com/transit-analytics-lab/spur

NSERC CRSNG

TAL TRANSIT ANALYTICS LAB

Current Landscape of Railway Simulations

Microscopic

- Highly detailed and realistic
- Long computation time and complex to set up, not suited for network-level analysis

Mesoscopic

- Useful results with minimal investment and fast computation
- Detailed where relevant, flexible in scale

Macroscopic

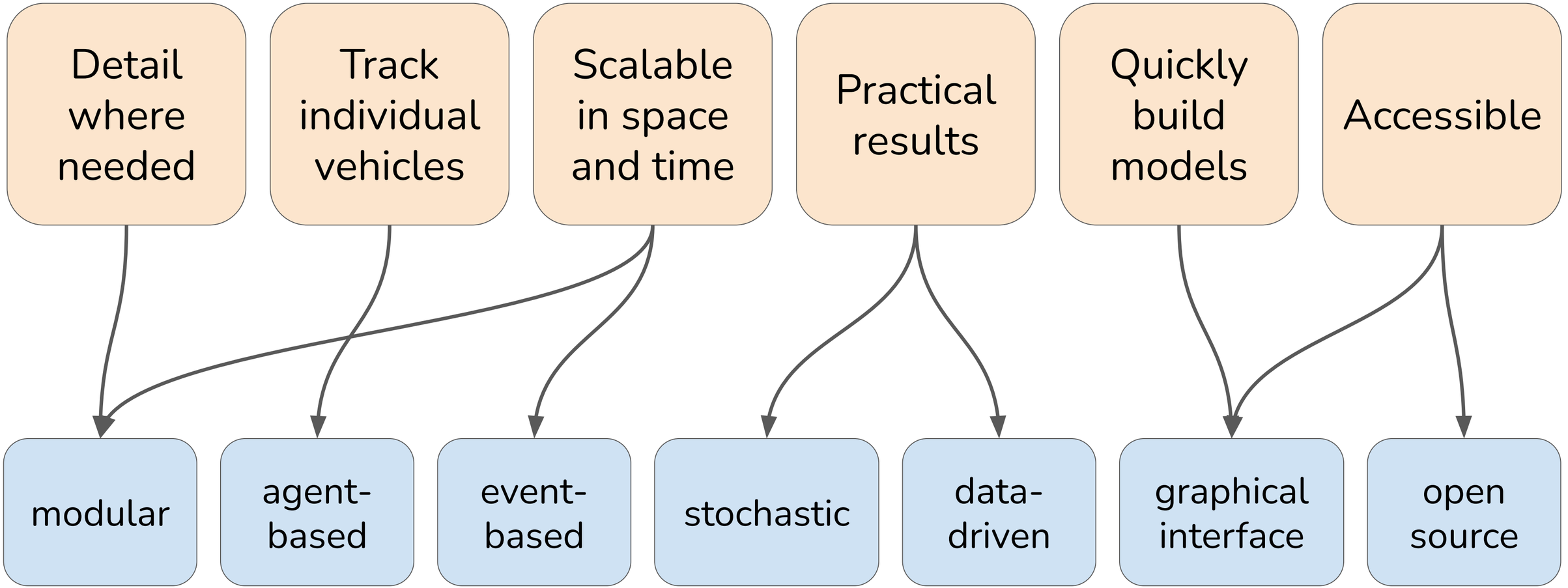
- Fast computation
- Only high-level, aggregate statistics about network-level performance

Aspect	Microscopic	Mesoscopic
Infrastructure	Realistic curves/grades	Abstracted to nodes/edges
Control	Specified in detail	Simplified logic
Movements	Detailed, physics-based	Based on fundamental properties
Data Requirements	Track-level detail	Network-level detail
Setup Difficulty	Requires detailed railway engineering knowledge	Fast prototyping, minimal railway knowledge
Network Size	Corridor level	Regional/national
Running Time	Extended	Short (possibly real-time)

Mesoscopic Railway Simulation in the Literature

Work	Scope	Application	Stochasticity	Availability
[1] Saidi et al. (2019)	Line	Control strategy evaluation	No	Proprietary
[2] Marinov and Viegas (2011)	Line + yards	Freight traffic	Yes	Proprietary
[3] Zhong et al. (2018)	Passenger stations	Capacity analysis	Yes	Proprietary
[4] Quaglietta et al. (2011)	Line + yards	Design and decision support	Yes	Proprietary
[5] Diviš and Kavička (2015)	Nodes	Capacity analysis	Yes	Proprietary
[6] Fabris et al. (2014)	Network	Timetable generation	Yes	Proprietary
[7] Kavička and Krýže (2021)	Network	Route planning	No	Proprietary

Spur: A flexible, mesoscopic railway simulation platform for rapid prototyping, simulation, and analysis.



“Big Picture” Railway Modelling

Test “outside the box” ideas

Look for larger effects

New service planning

Network capacity analysis

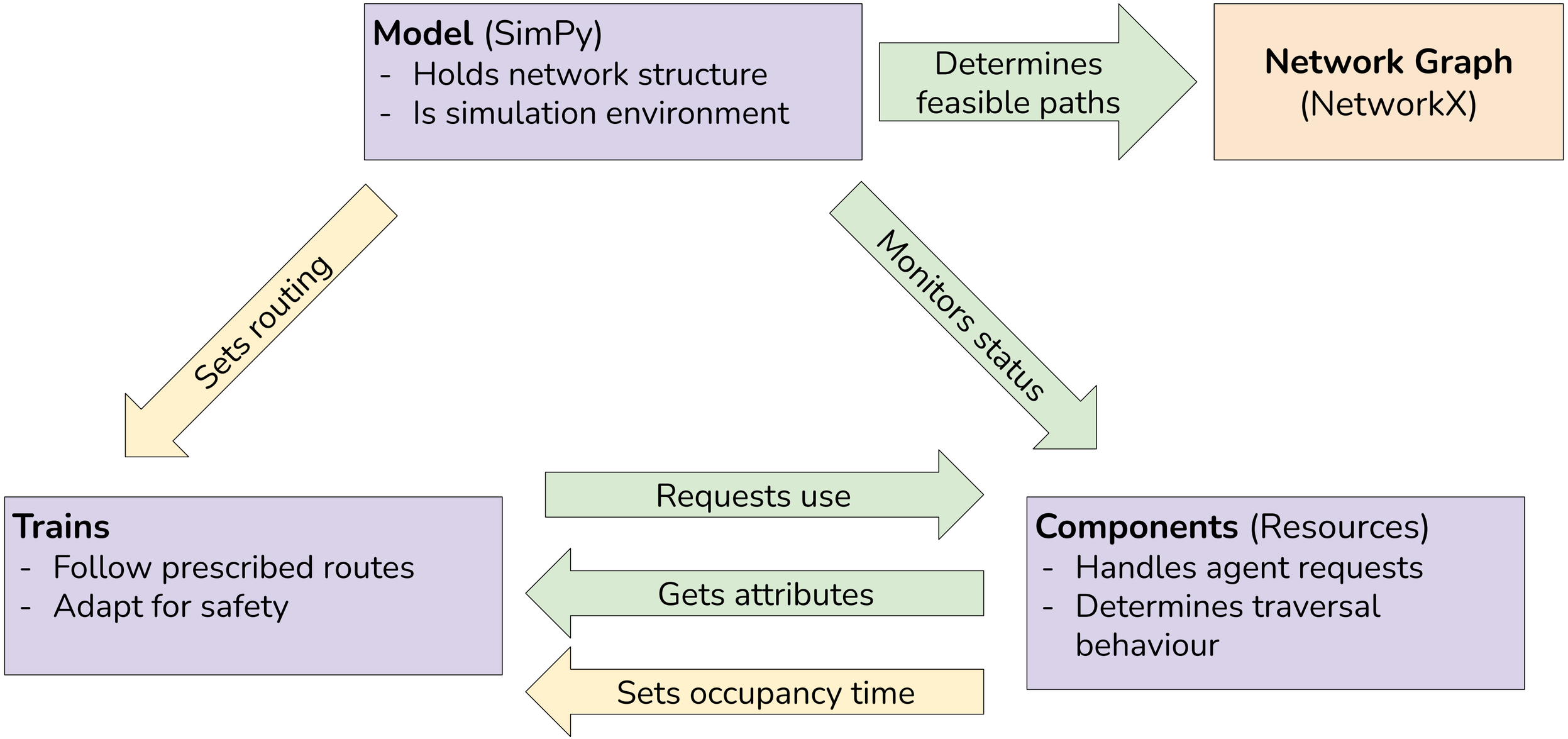
Simulation-driven optimization

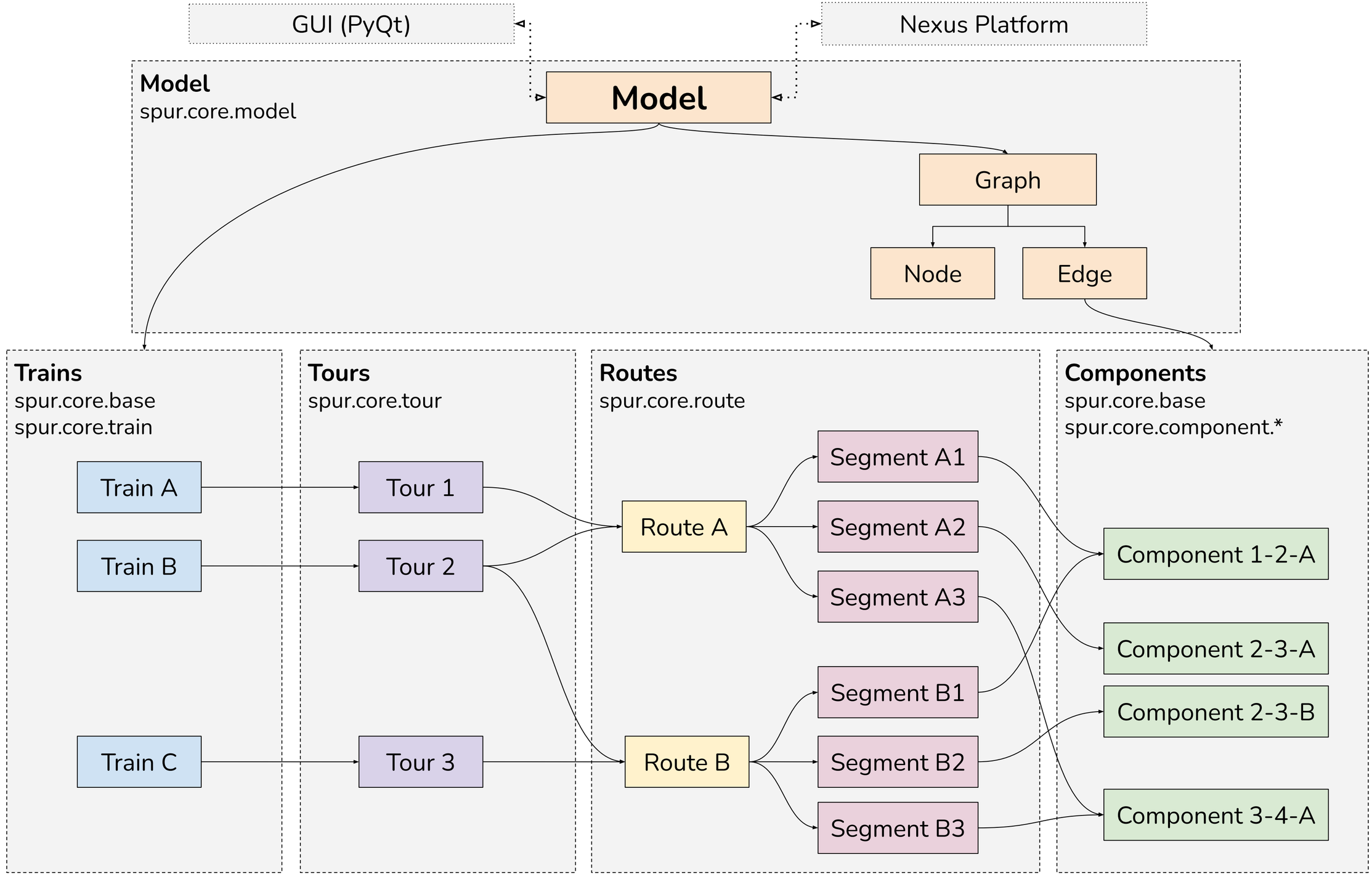
Timetables | Routing | Control algorithms

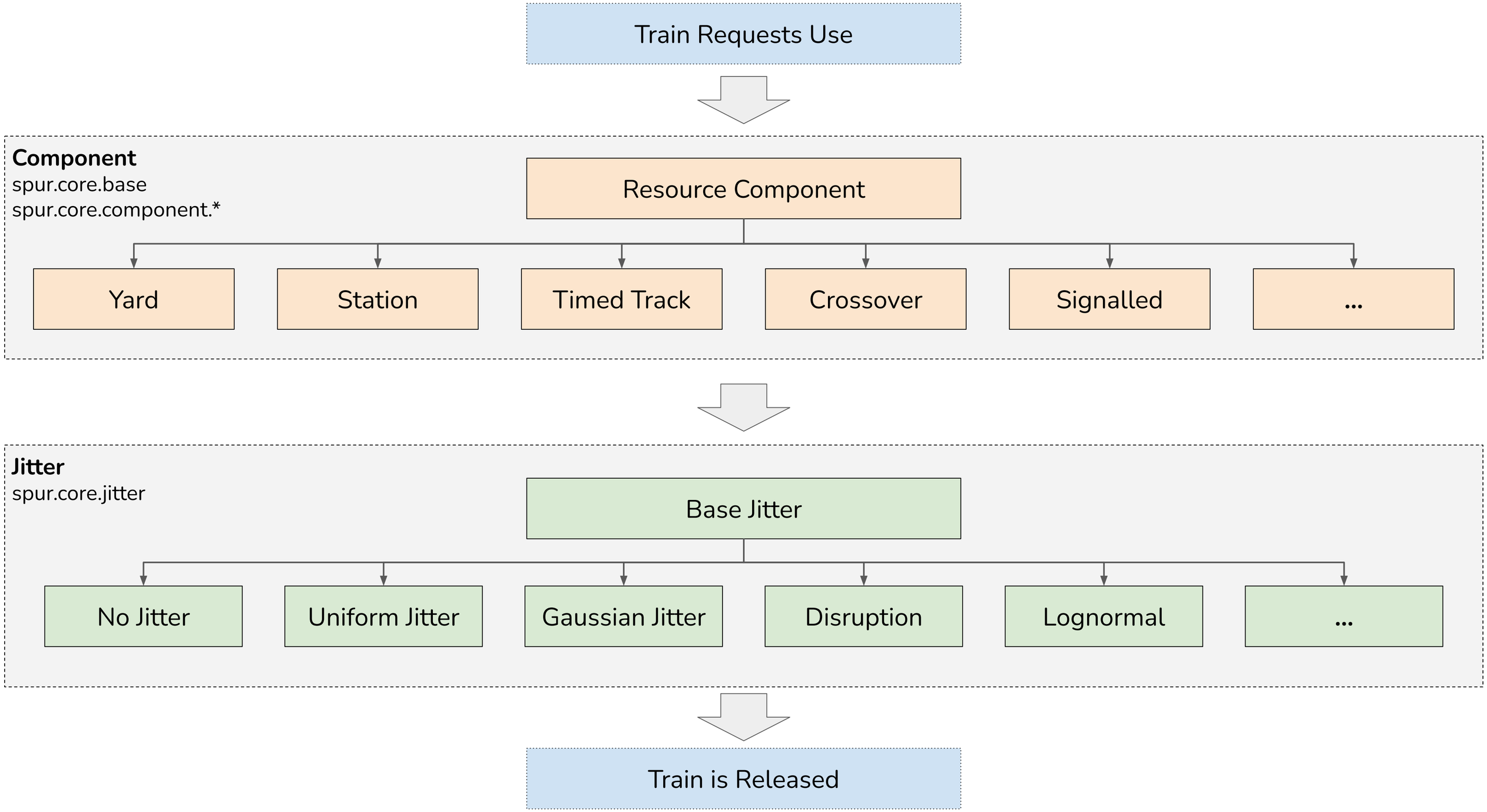
Disruption management

Integration with pedestrian flow simulations (Nexus)

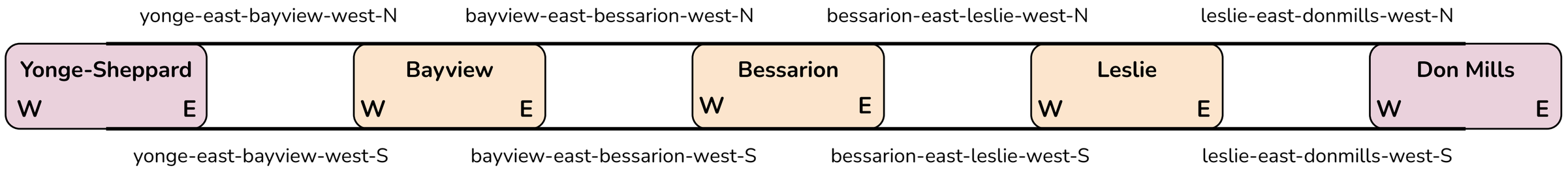
Architecture




GUI (PyQt)
Nexus Platform
Model
spur.core.model
Model
Graph
Node
Edge
Trains
spur.core.base
spur.core.train
Train A
Train B
Train C
Tours
spur.core.tour
Tour 1
Tour 2
Tour 3
Routes
spur.core.route
Route A
Route B
Segment A1
Segment A2
Segment A3
Segment B1
Segment B2
Segment B3
Components
spur.core.base
spur.core.component.*
Component 1-2-A
Component 2-3-A
Component 2-3-B
Component 3-4-A

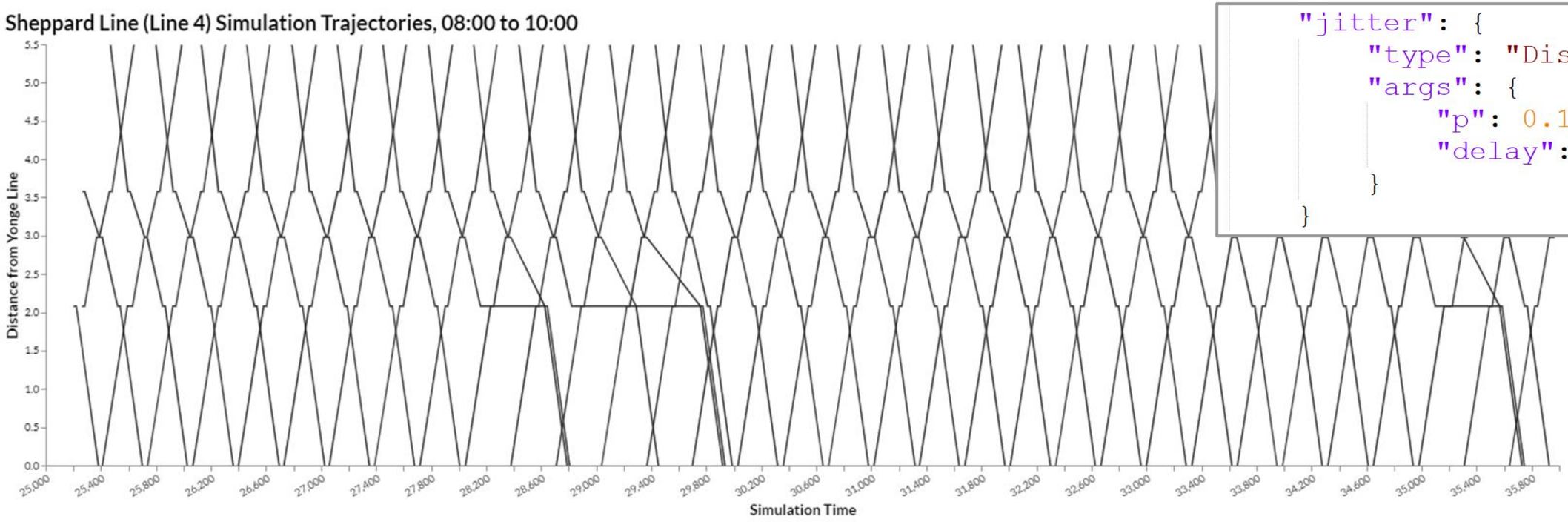

Train Requests Use
Component
spur.core.base
spur.core.component.*
Resource Component
Yard
Station
Timed Track
Crossover
Signalled
...
Jitter
spur.core.jitter
Base Jitter
No Jitter
Uniform Jitter
Gaussian Jitter
Disruption
Lognormal
...
Train is Released

Example: TTC Line 4

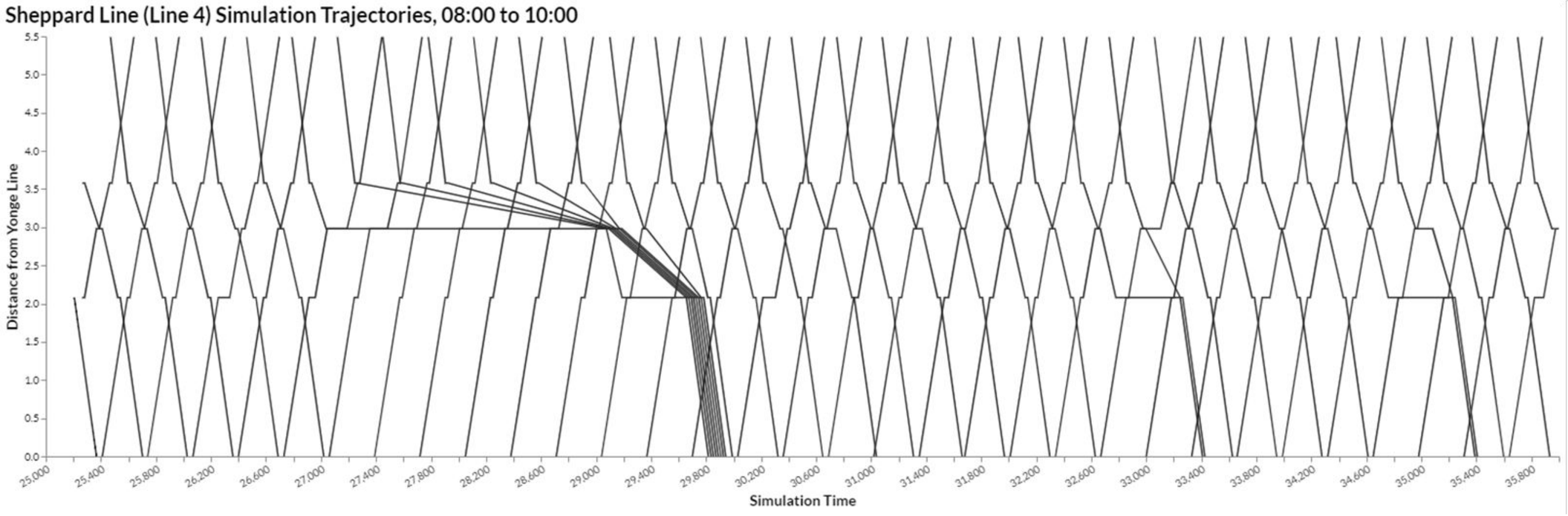


GTFS

	pair	pair_id	travel	
			mean	std
0	Bayview Station - Eastbound Platform to Bessarion Station - Eastbound Platform	14531 to 14532	87.0	0.0
1	Bayview Station - Westbound Platform to Sheppard-Yonge Station - Subway Platform	14538 to 14539	161.0	0.0
2	Bessarion Station - Eastbound Platform to Leslie Station - Eastbound Platform	14532 to 14533	75.0	0.0
3	Bessarion Station - Westbound Platform to Bayview Station - Westbound Platform	14537 to 14538	113.0	0.0
4	Don Mills Station - Westbound Platform to Leslie Station - Westbound Platform	14535 to 14536	125.0	0.0
5	Leslie Station - Eastbound Platform to Don Mills Station - Subway Platform	14533 to 14534	159.0	0.0
6	Leslie Station - Westbound Platform to Bessarion Station - Westbound Platform	14536 to 14537	105.0	0.0
7	Sheppard-Yonge Station - Eastbound Platform to Bayview Station - Eastbound Platform	14530 to 14531	183.0	0.0




```
    "jitter": {
        "type": "DisruptionJitter",
        "args": {
            "p": 0.1,
            "delay": 450
        }
    }
```



Ongoing & Future Work

Short-term:

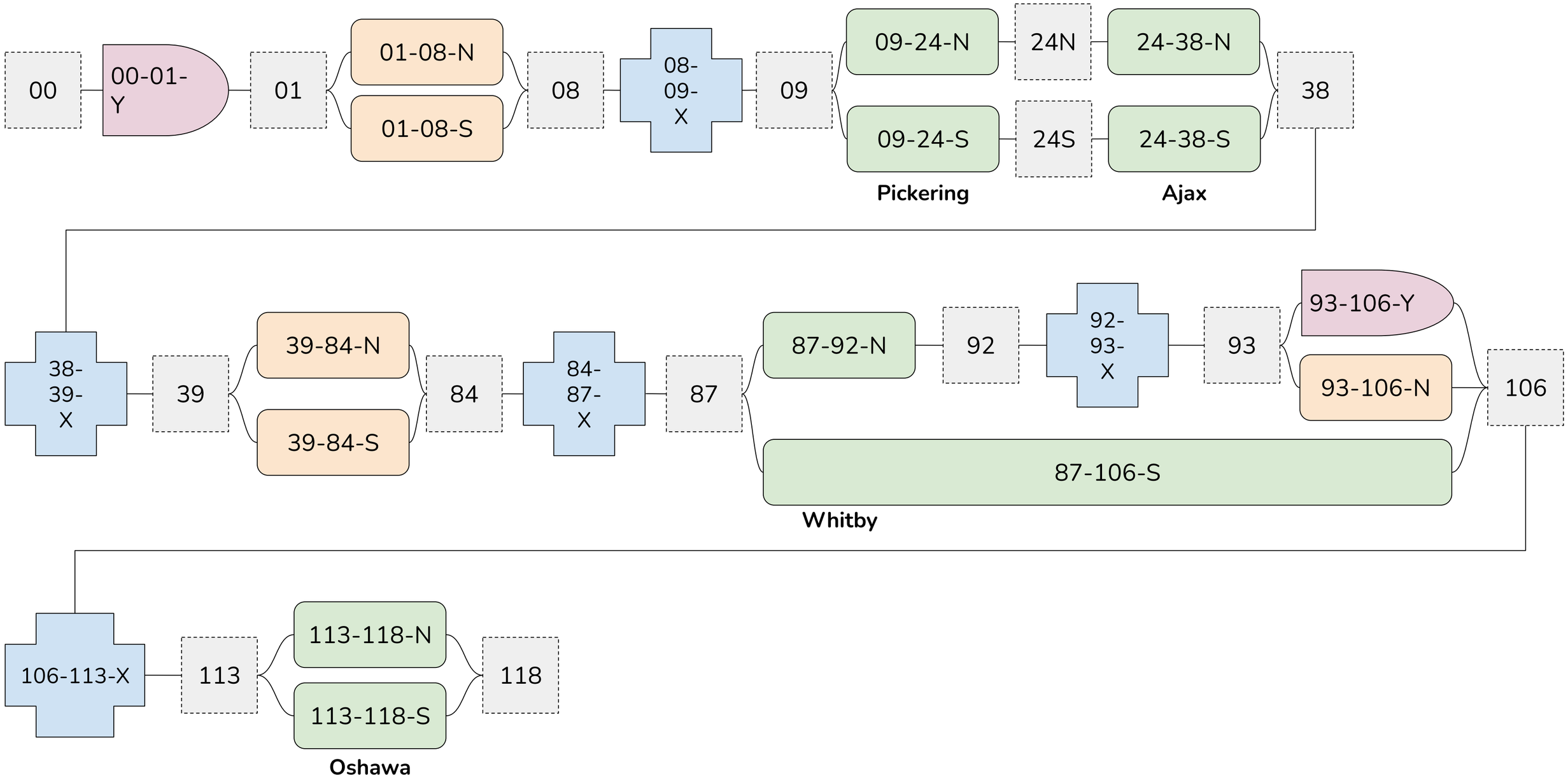
Simulating the entire GO Train network in Spur

- New components
- Calibration and validation
- Automating GTFS import

Medium to long-term:

- Full graphical interface for model construction
- Central controller for more complex dispatching tasks
- …

Simulating the GO Network with Spur



Contributions and questions welcome!

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References

[1] S. Saidi, N. H. M. Wilson, H. N. Koutsopoulos, and J. Zhao, “Mesoscopic Modeling of Train Operations: Application to the MBTA Red Line,” in *2019 IEEE Intelligent Transportation Systems Conference (ITSC)*, Oct. 2019, pp. 98–103. doi: 10.1109/ITSC.2019.8917313.

[2] M. Marinov and J. Viegas, “A mesoscopic simulation modelling methodology for analyzing and evaluating freight train operations in a rail network,” *Simulation Modelling Practice and Theory*, vol. 19, no. 1, pp. 516–539, Jan. 2011, doi: 10.1016/j.simpat.2010.08.009.

[3] M. Zhong, Y. Yue, and D. Li, “Analyzing and Evaluating Infrastructure Capacity of Railway Passenger Station by Mesoscopic Simulation Method,” in *2018 International Conference on Intelligent Rail Transportation (ICIRT)*, Singapore, Dec. 2018, pp. 1–5. doi: 10.1109/ICIRT.2018.8641593.

[4] E. Quaglietta, L. D’Acierno, V. Punzo, R. Nardone, and N. Mazzocca, “A simulation framework for supporting design and real-time decisional phases in railway systems,” in *2011 14th International IEEE Conference on Intelligent Transportation Systems (ITSC)*, Washington, DC, USA, Oct. 2011, pp. 846–851. doi: 10.1109/ITSC.2011.6082913.

[5] R. Diviš and A. Kavička, “Design and development of a mesoscopic simulator specialized in investigating capacities of railway nodes,” presented at the 27th European Modeling and Simulation Symposium, Sep. 2015, pp. 52–57.

[6] S. de Fabris, G. Longo, G. Medeossi, and R. Pesenti, “Automatic generation of railway timetables based on a mesoscopic infrastructure model,” *Journal of Rail Transport Planning & Management*, vol. 4, no. 1–2, pp. 2–13, Aug. 2014, doi: 10.1016/j.jrtpm.2014.04.001.

[7] A. Kavička and P. Krýže, “Dynamic Automated Search of Shunting Routes within Mesoscopic Rail-Traffic Simulators,” *Journal of Advanced Transportation*, vol. 2021, pp. 1–22, Apr. 2021, doi: 10.1155/2021/8840516.