Stress-Minimizing Orthogonal Layout of Data Flow Diagrams with Ports

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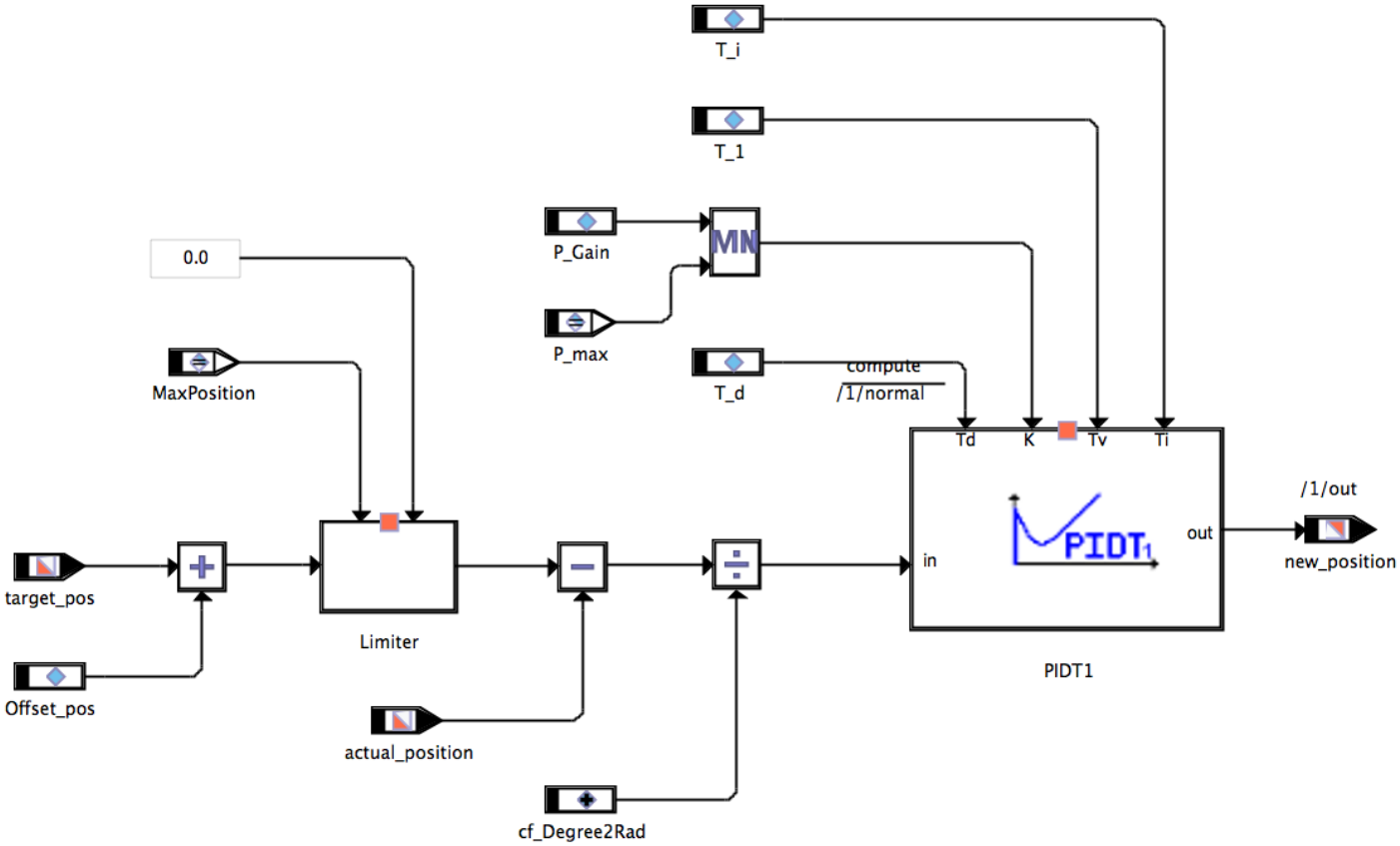
Graph Drawing 2014

Background: Automotive Industry



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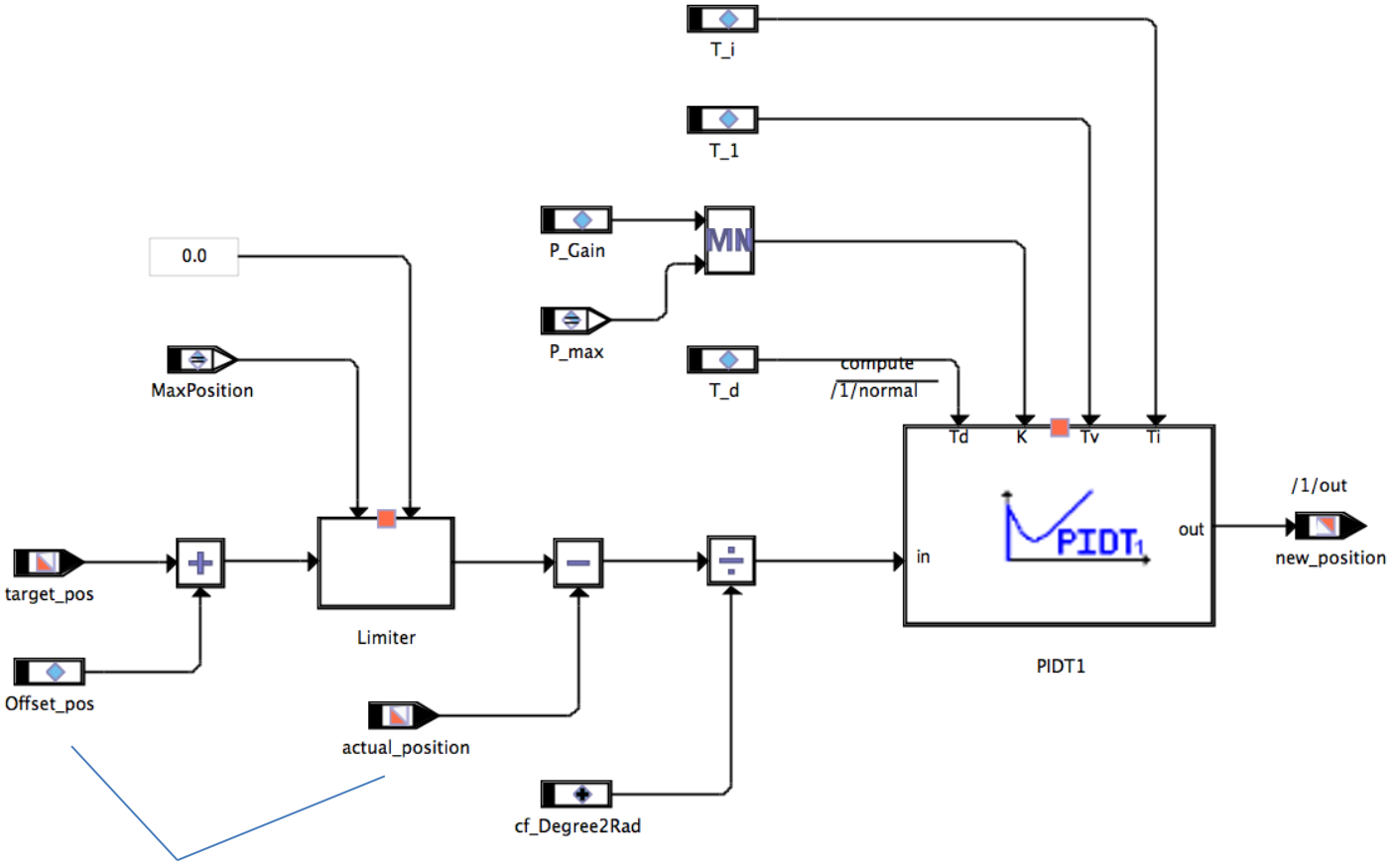

ATOMIC NODES

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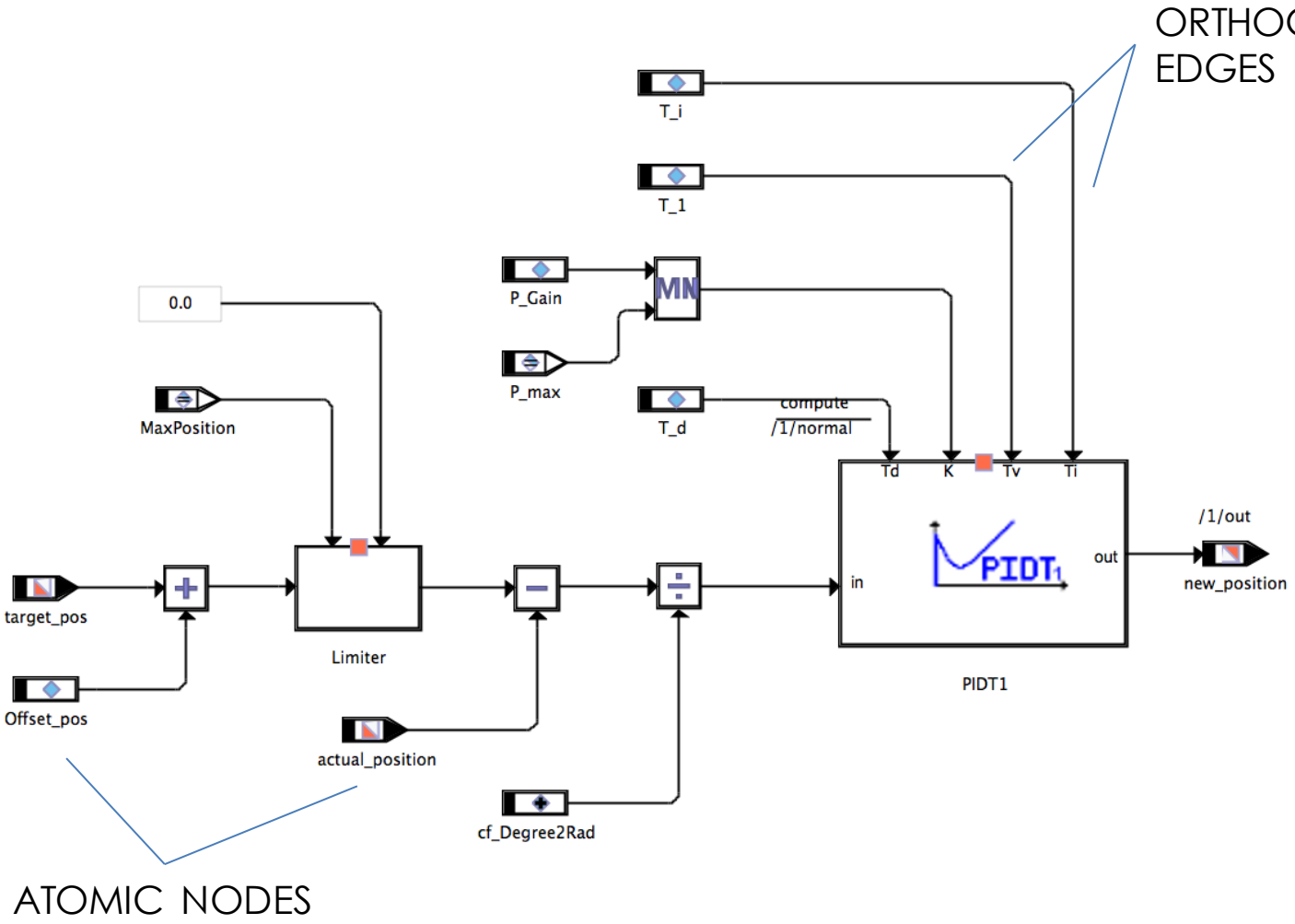

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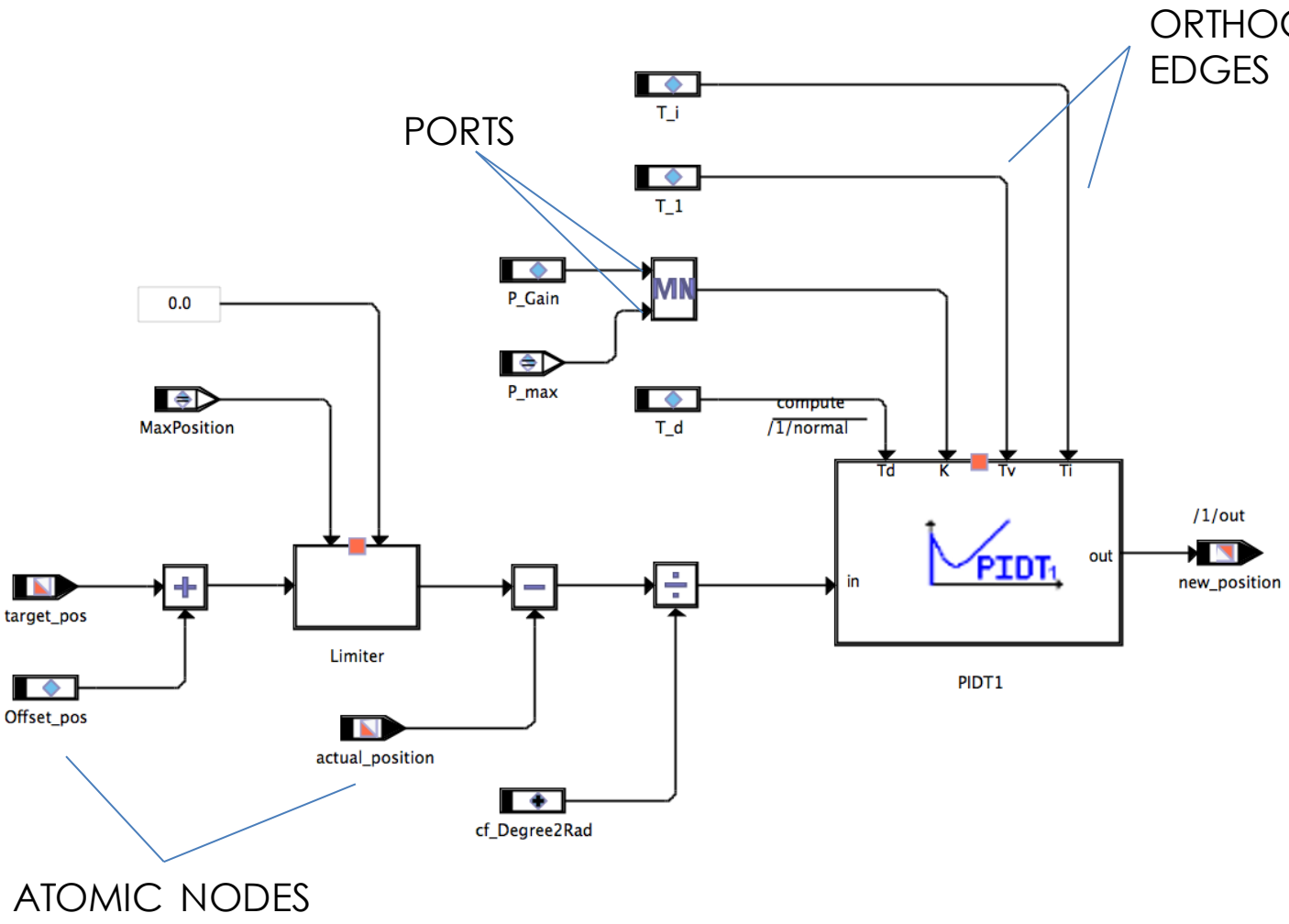

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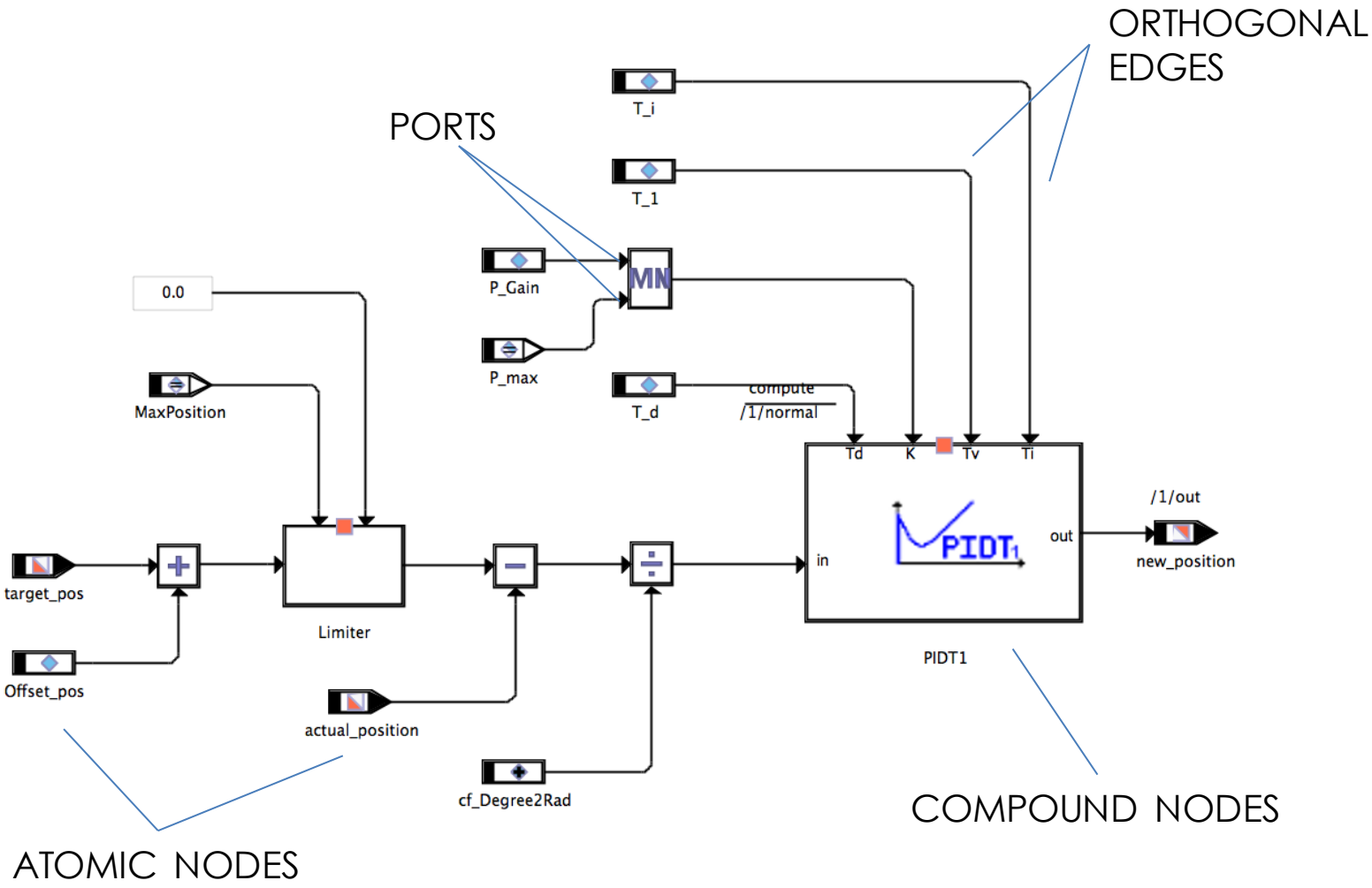

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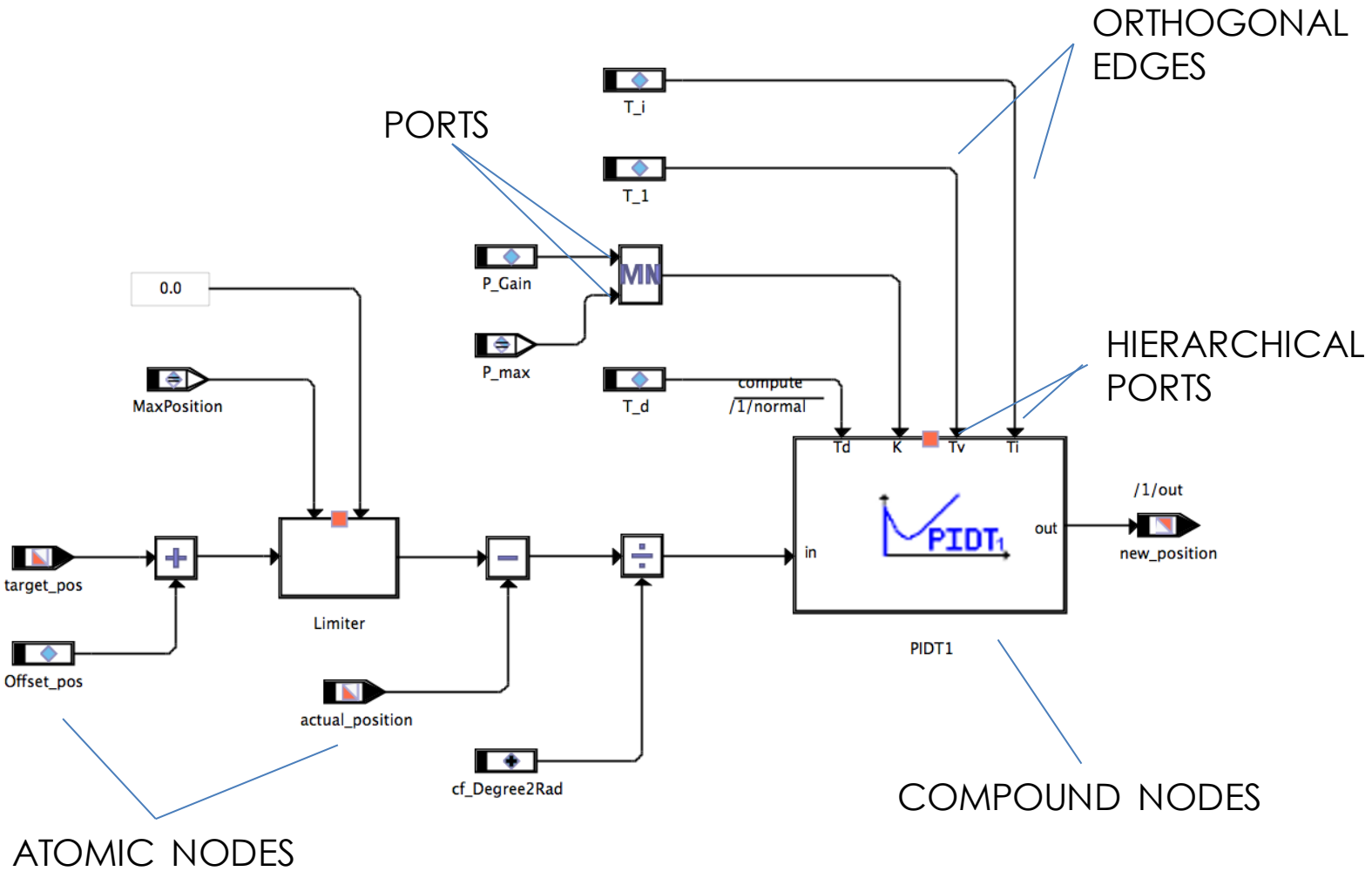
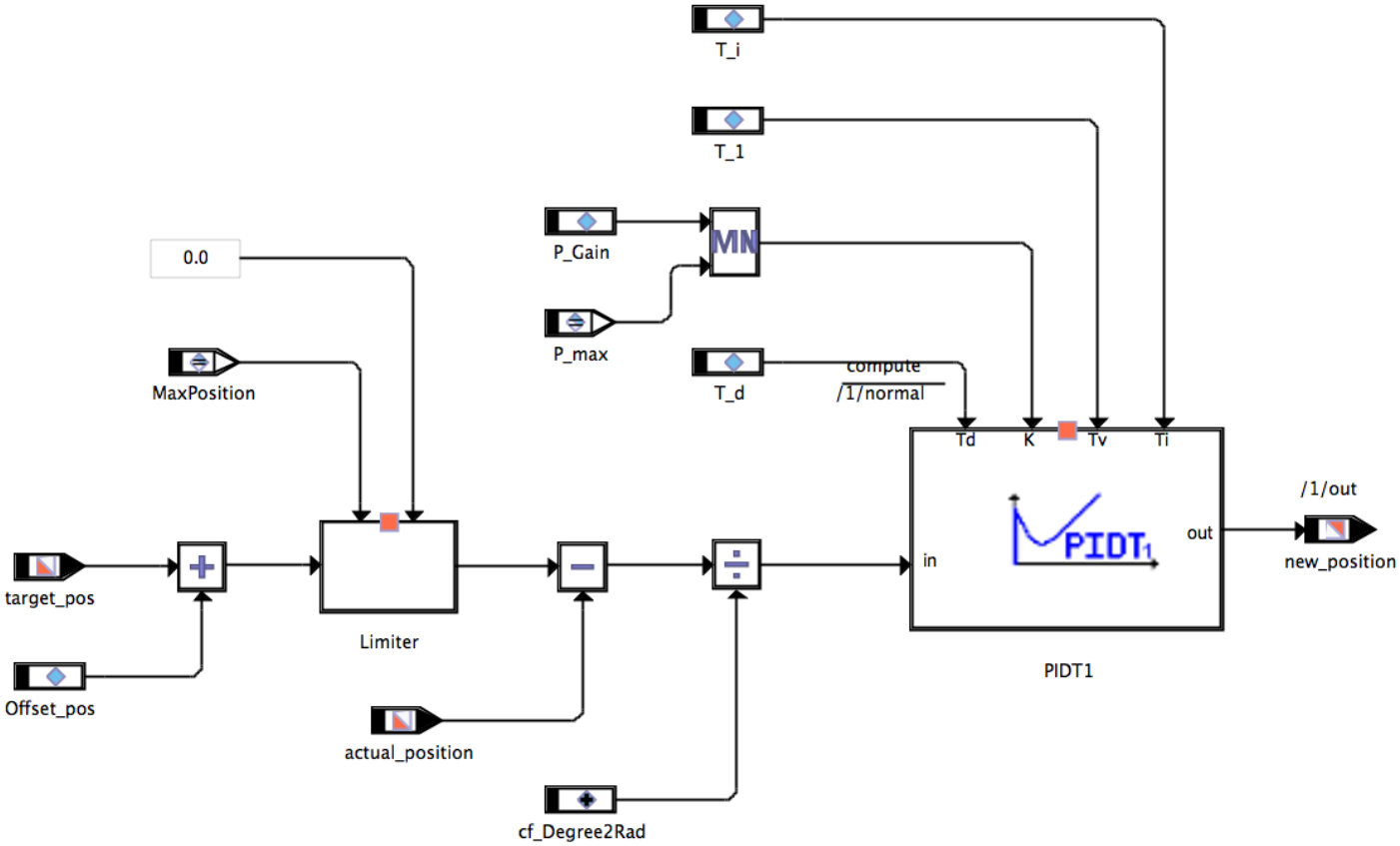


Layout Requirements



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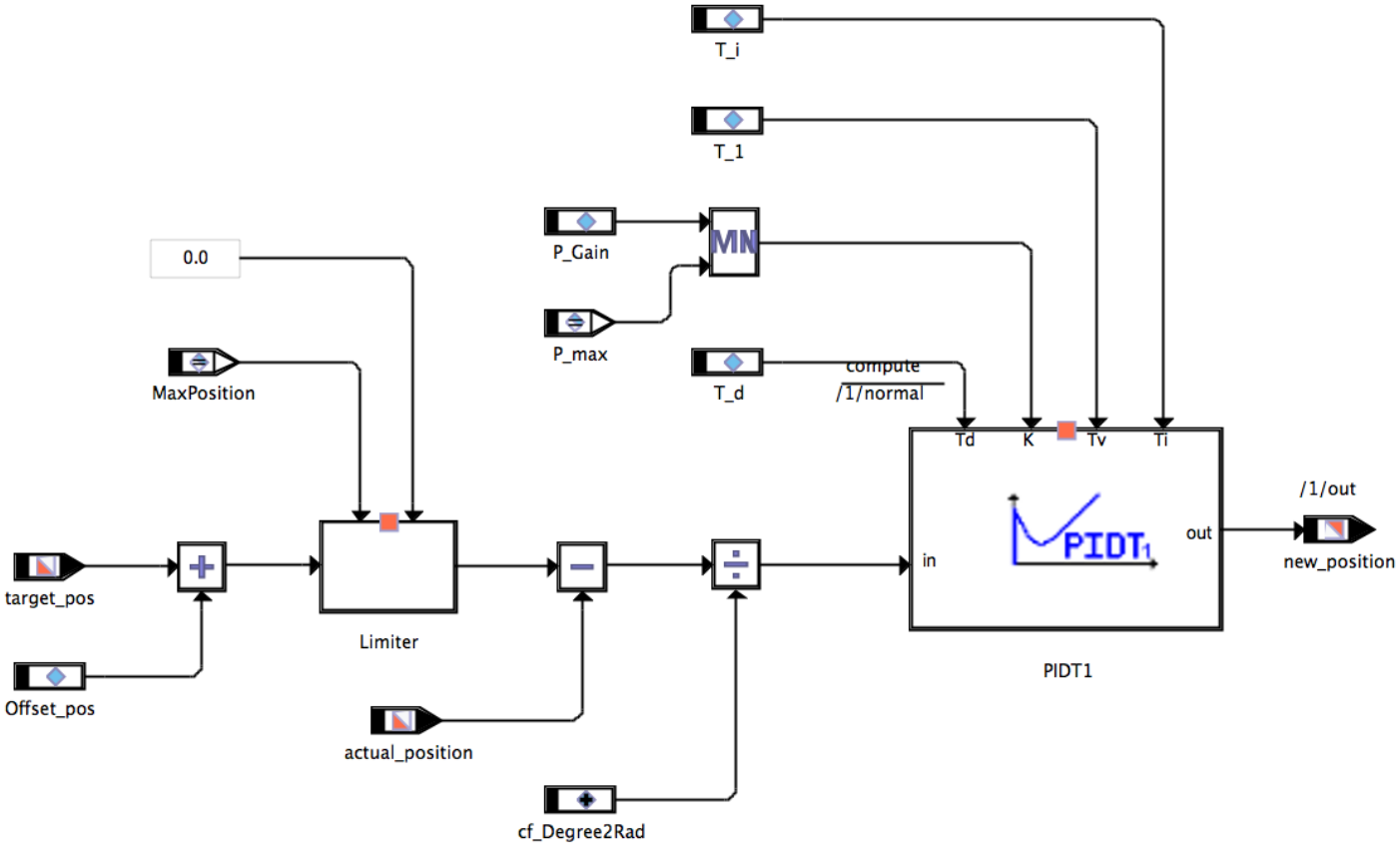
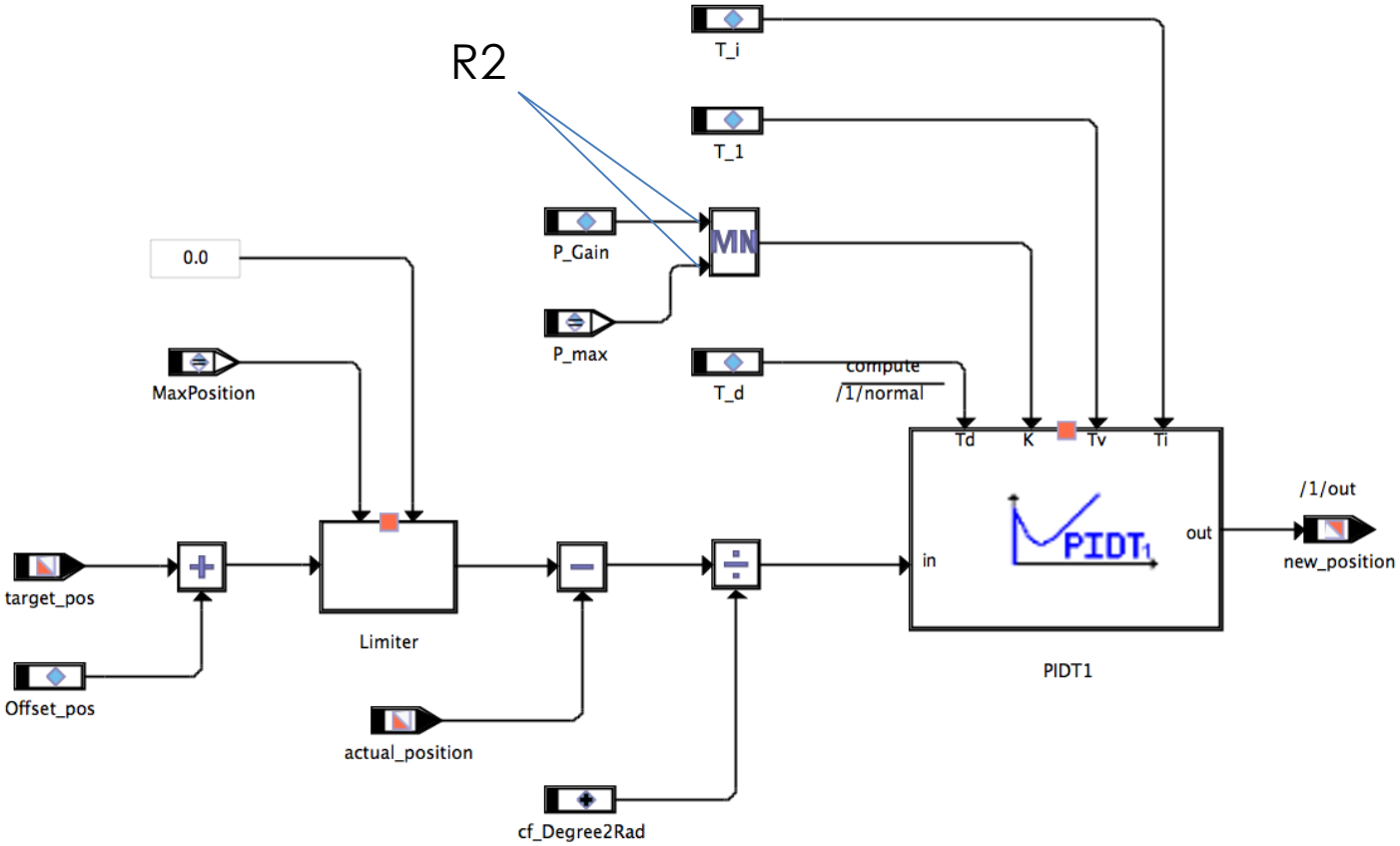


R1

Layout Requirements



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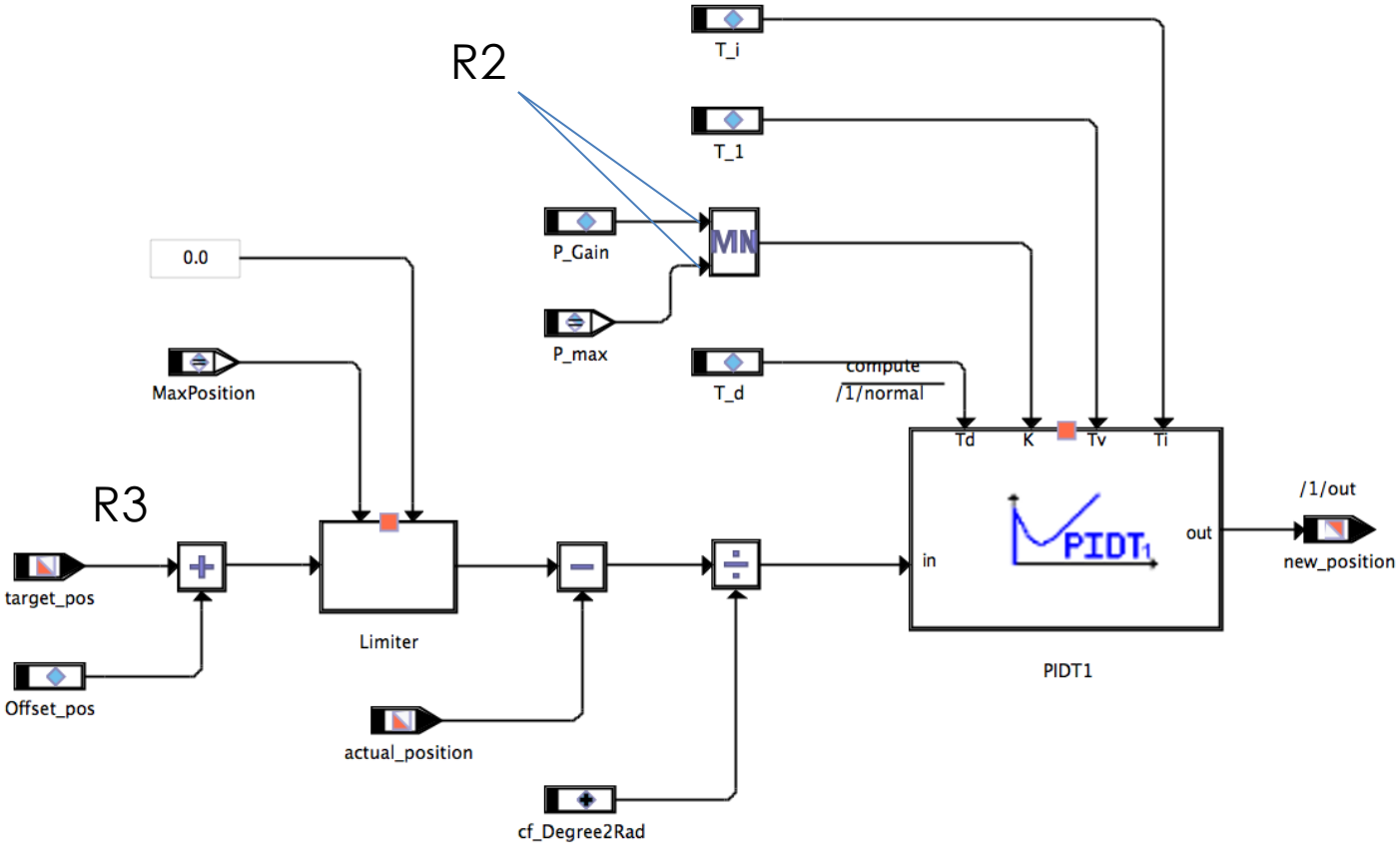

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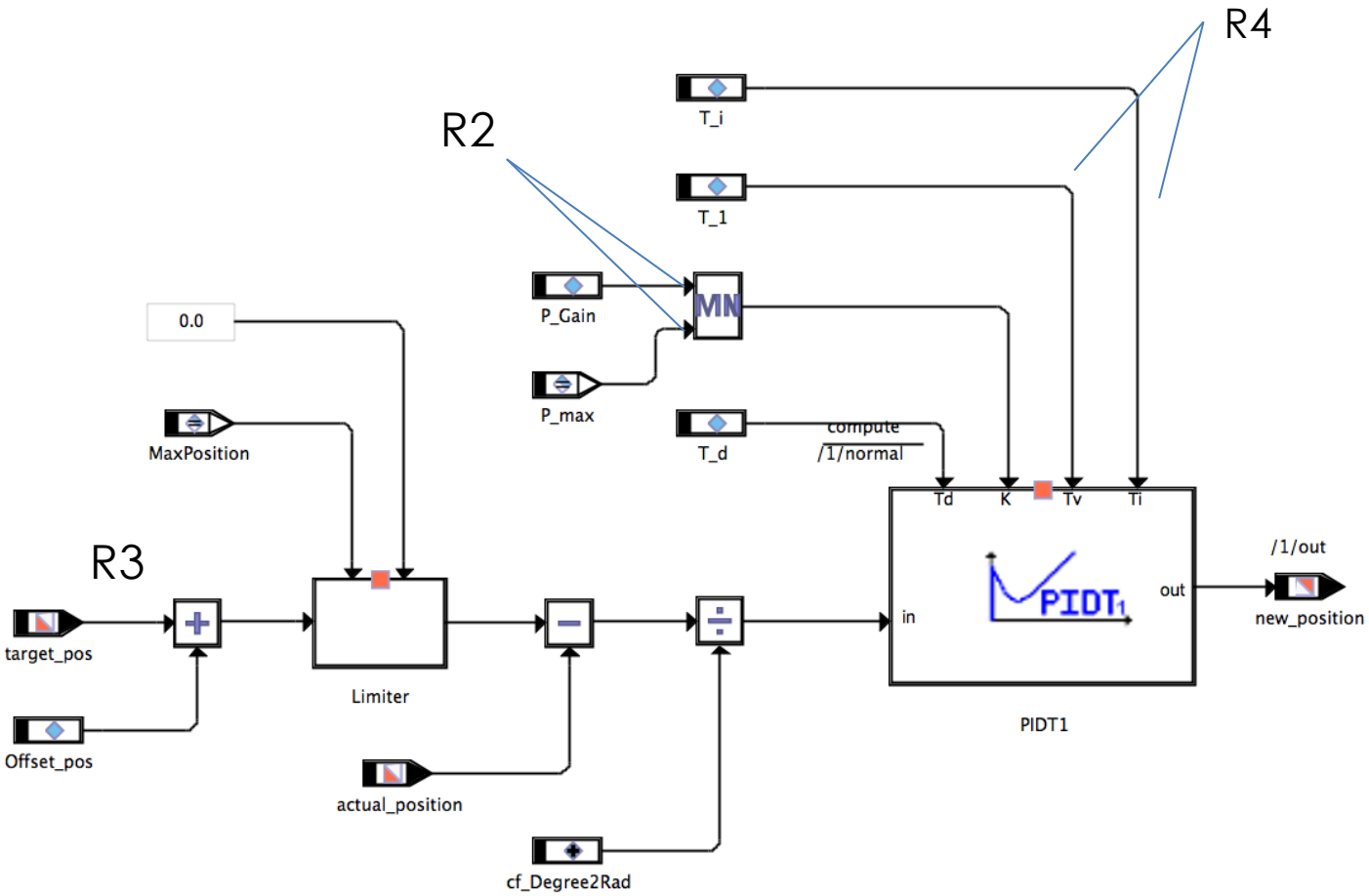

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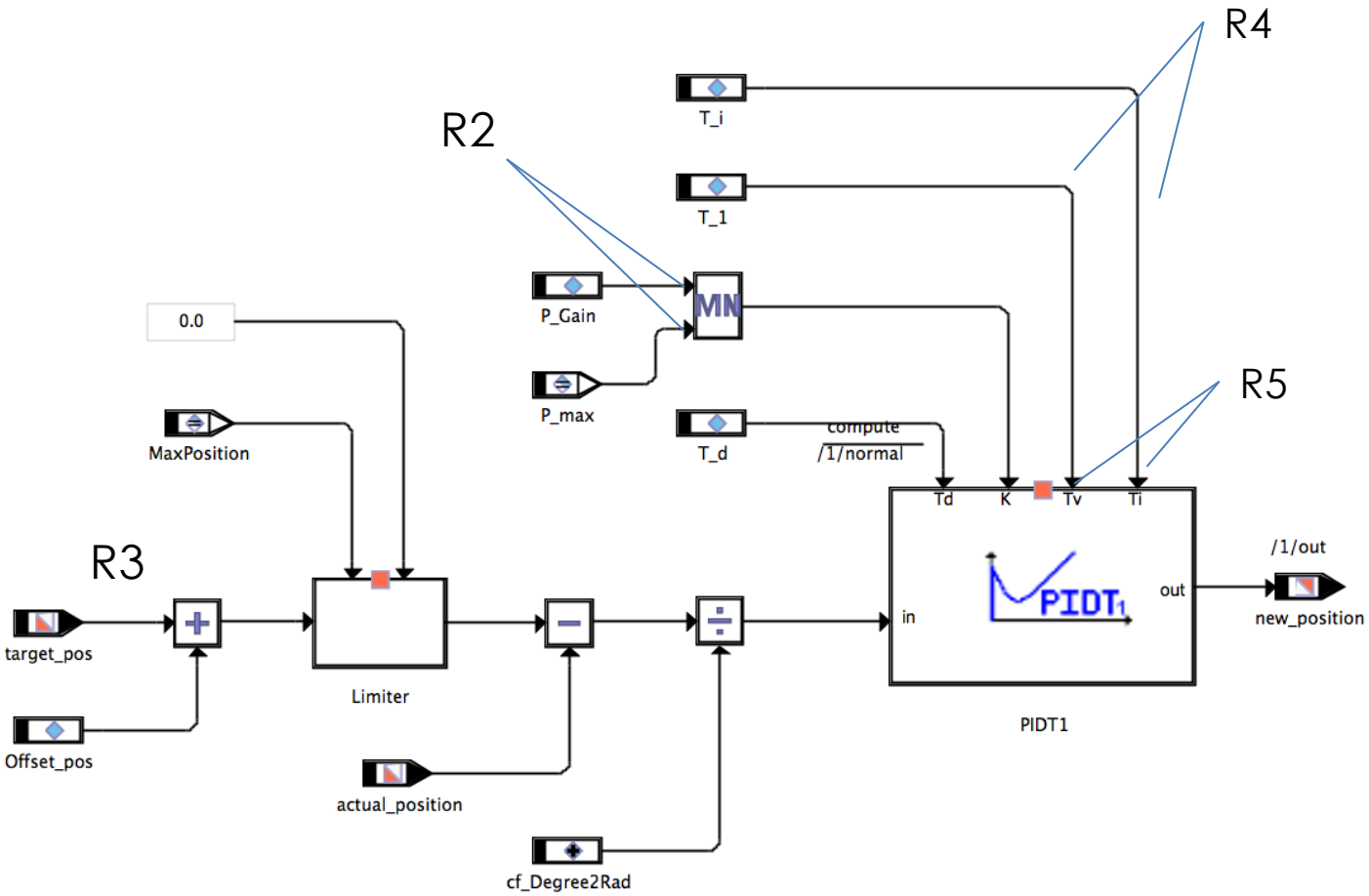

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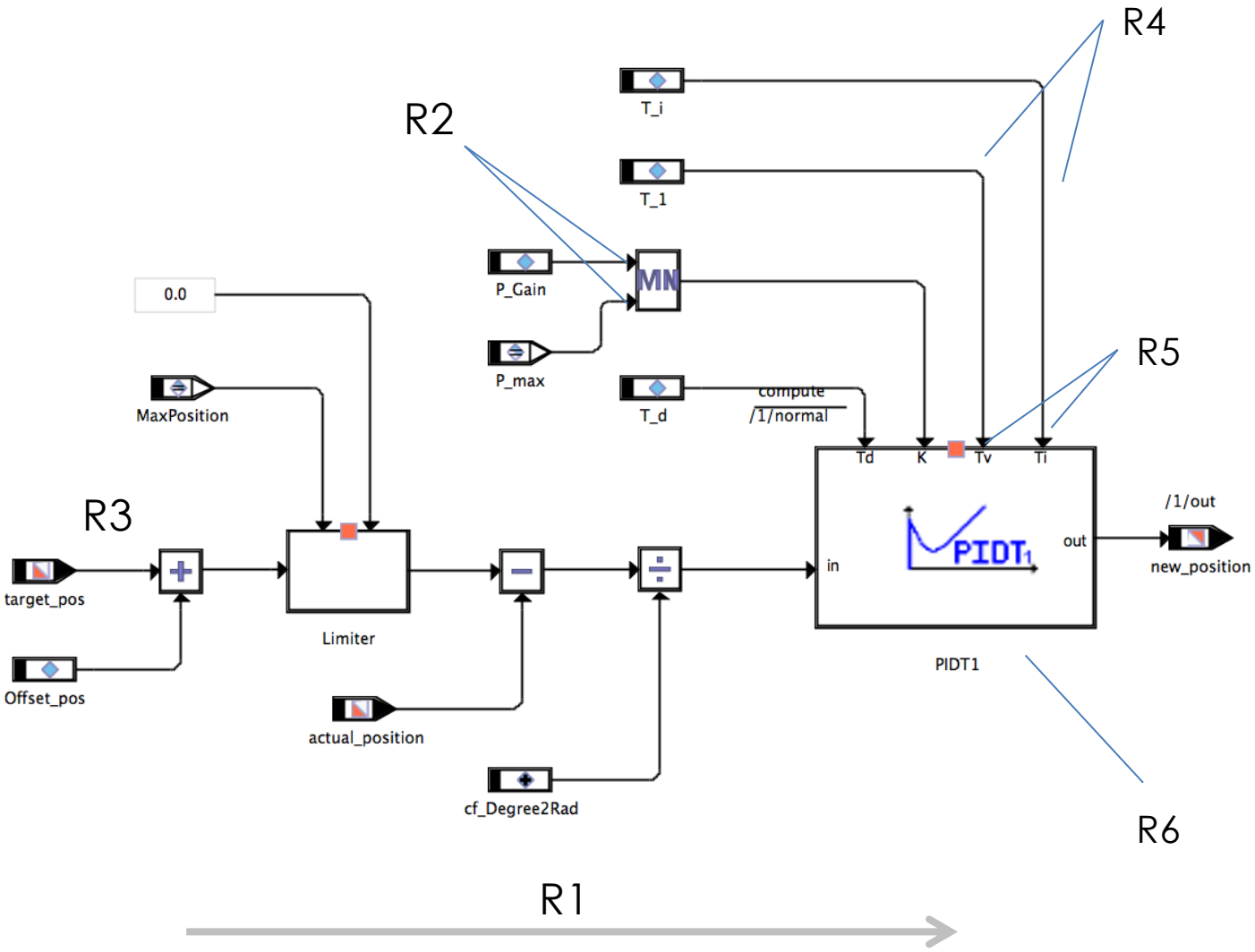

Current Layout Approach

- Use layer-based methods [Sugiyama et al. 81]
  - A lot of modifications (ports etc.) [Schulze et al. 14]

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➢ Desired: simple/flexible solution

New Approach

- Constrained stress minimizing layout

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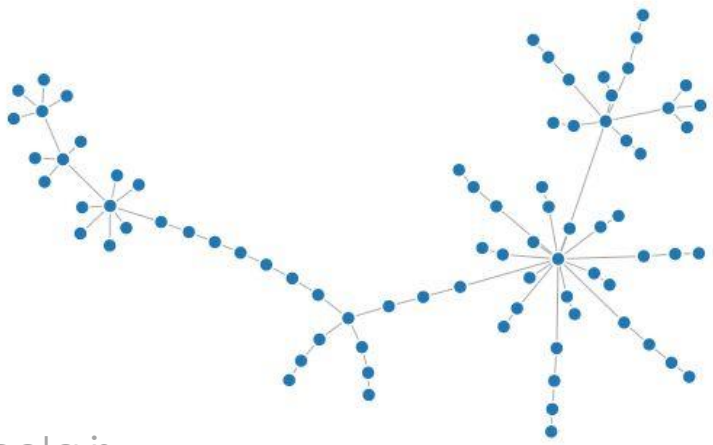
  - Similar to force-directed approaches



cola.js

New Approach

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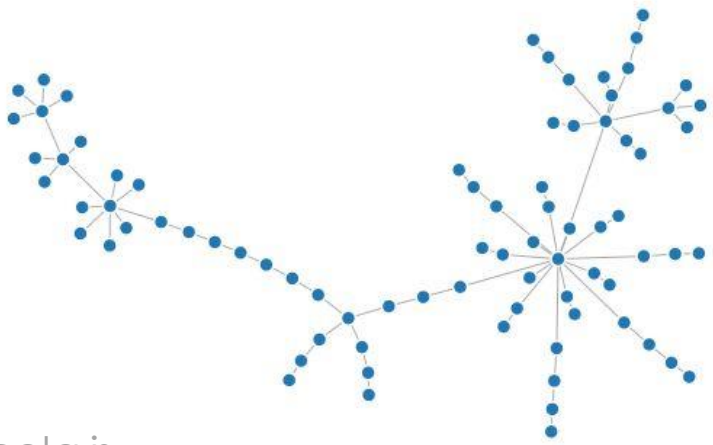
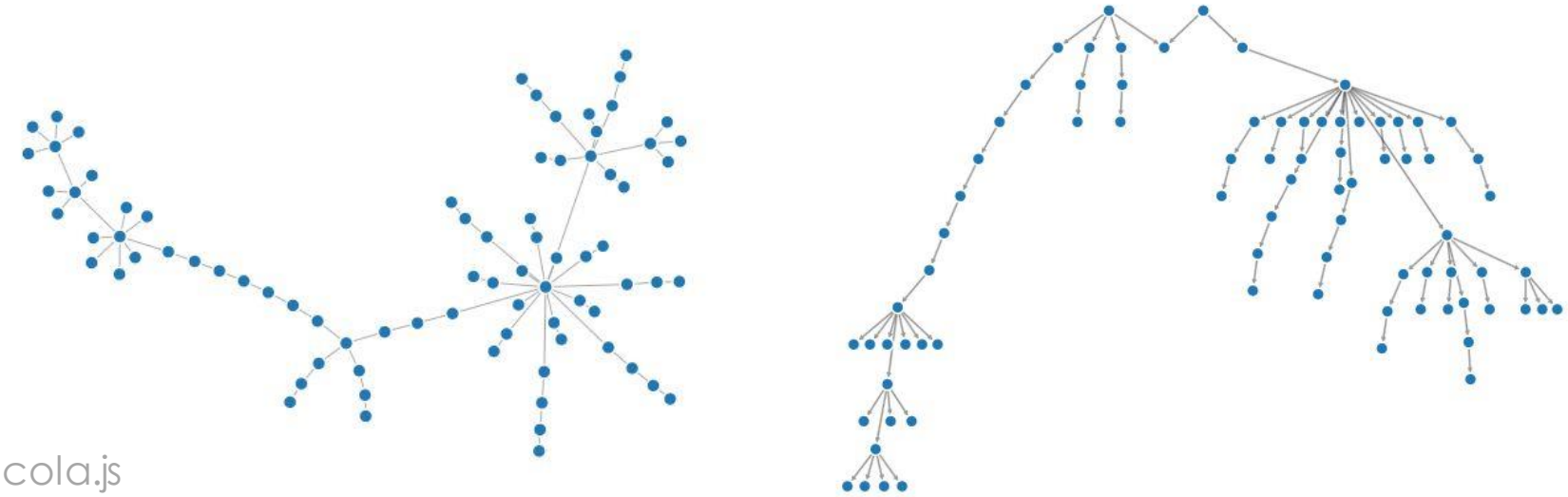


cola.js

New Approach

- Constrained stress minimizing layout
  - Similar to force-directed approaches
  - Minimizes a single goal function
  - Subject to separation constraints



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Goal Function: P-Stress

Minimize

$$\sum_{u<v\in V} w_{uv}\left((lp_{uv} - b(u,v))^{+}\right)^2 + \sum_{(u,v)\in E} l^{-2}\left((b(u,v) - l)^{+}\right)^2$$

subject to certain constraints

[Dwyer et al. GD'09]

Goal Function: P-Stress

Minimize

$$\underbrace{\sum_{u<v\in V} w_{uv}\left((lp_{uv} - b(u,v))^{+}\right)^{2}}_{\text{repulsive}} + \underbrace{\sum_{(u,v)\in E} l^{-2}\left((b(u,v) - l)^{+}\right)^{2}}_{\text{attractive}}$$

subject to certain constraints

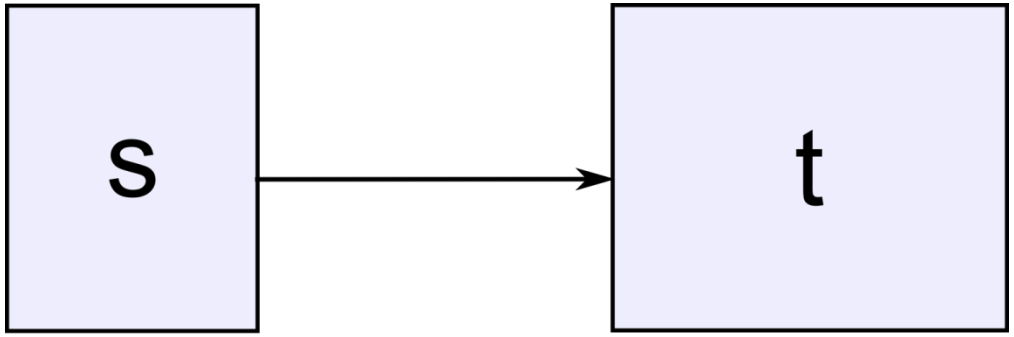
INTUITION

- Nodes repulse each other up to a certain distance
- Edges contract until (individual) ideal length is reached

$b(u,v)$	euclidean distance between u and v
p_{uv}	number of edges on shortest path between u and v
l	an ideal edge length
w_{uv}	normalization factor
$(z)^{+}$	$\max(0,z)$

[Dwyer et al. GD'09]

R1 - Flow Constraints



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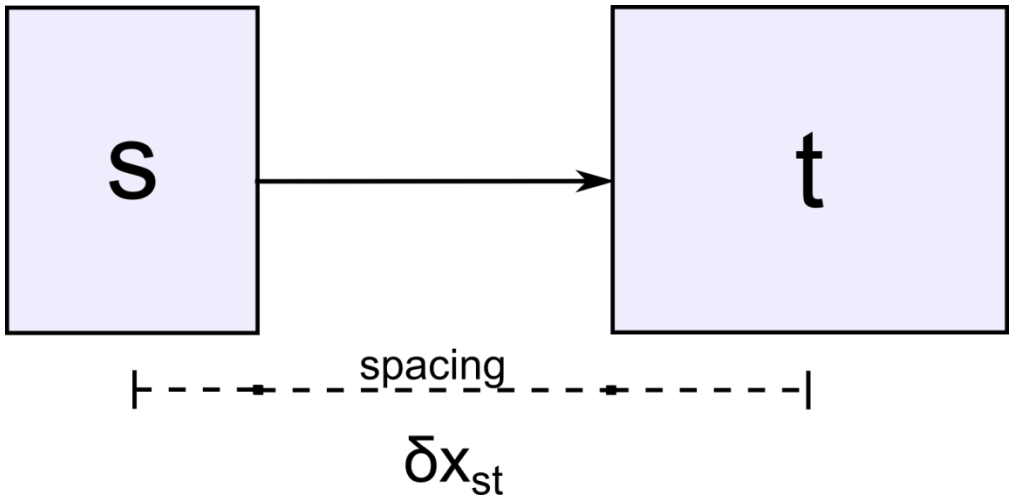
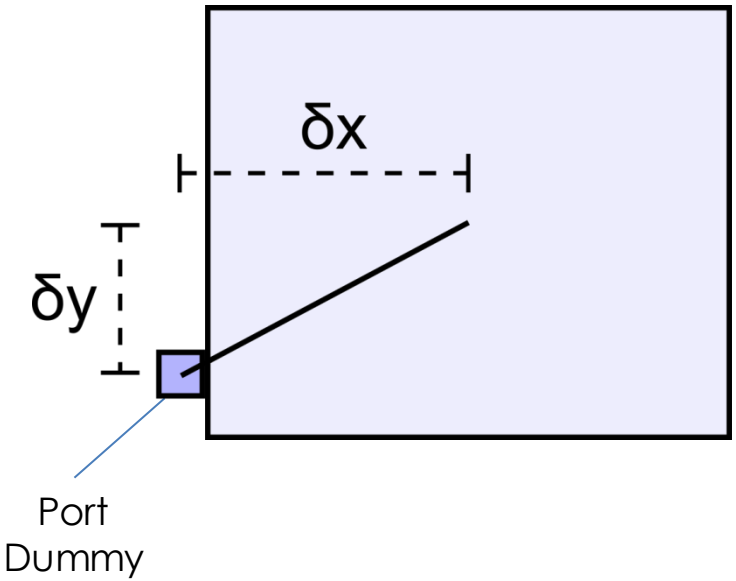


$$x_s + \delta x_{st} \leq x_t$$

R2 - Port Constraints

FIXED POSITION



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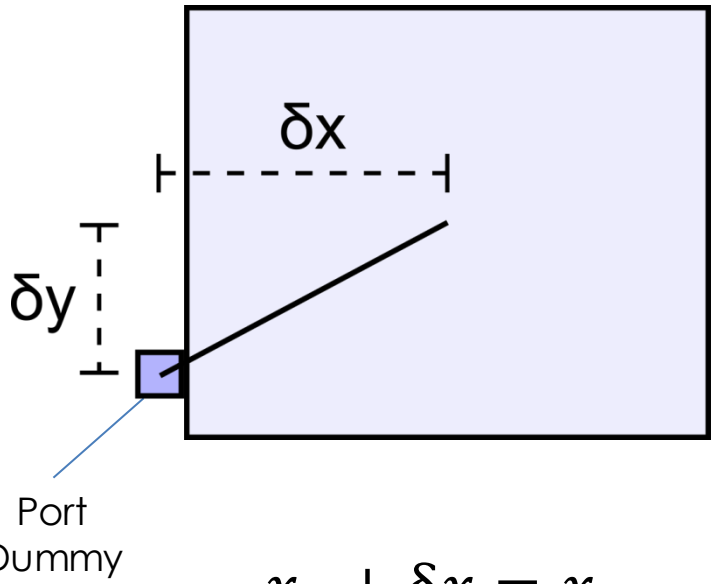

$$x_p + \delta x = x_n$$

$$y_p - \delta y = y_n$$

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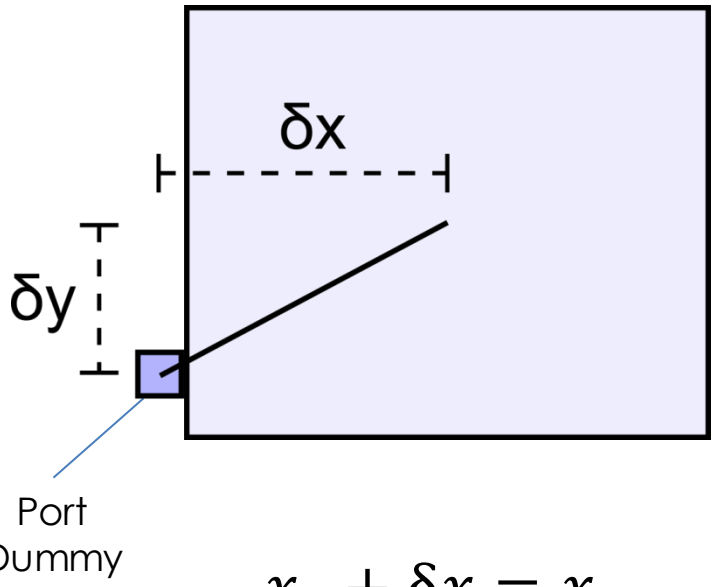
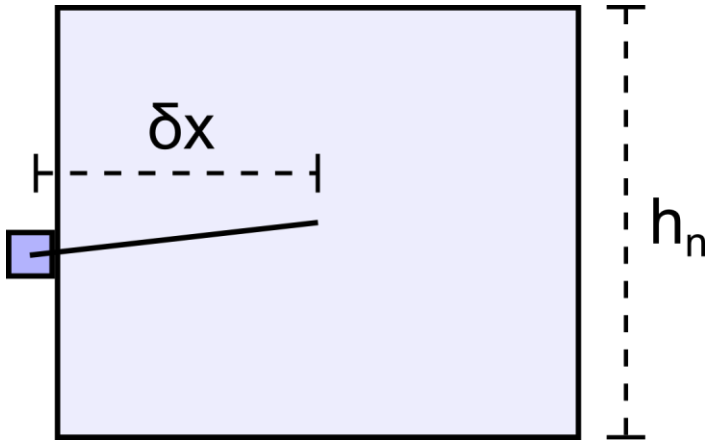


FIXED SIDE



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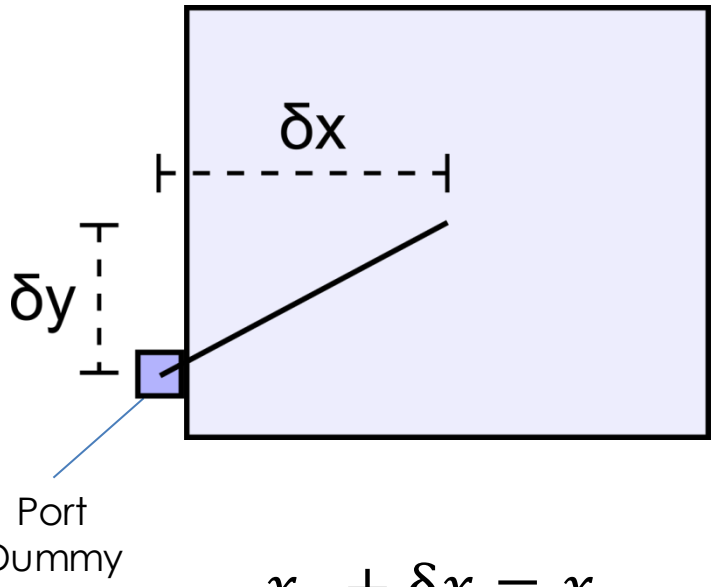

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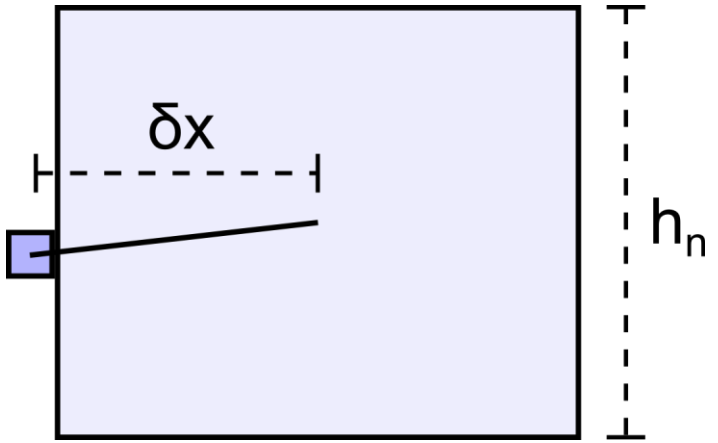

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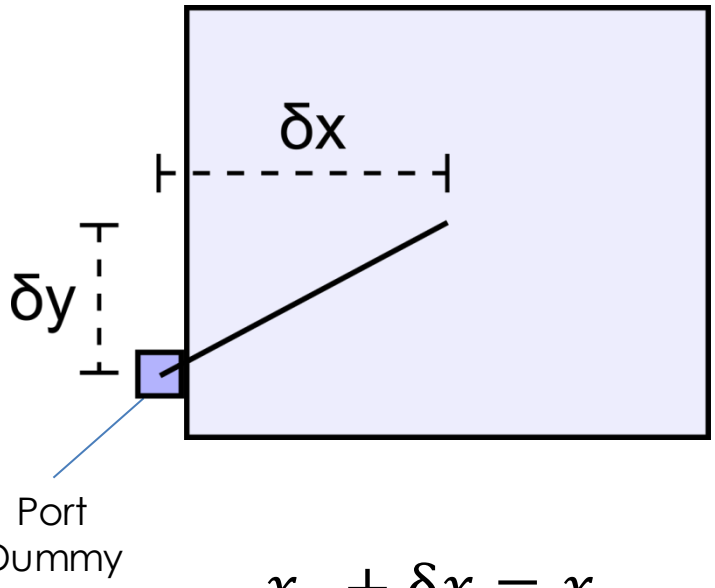

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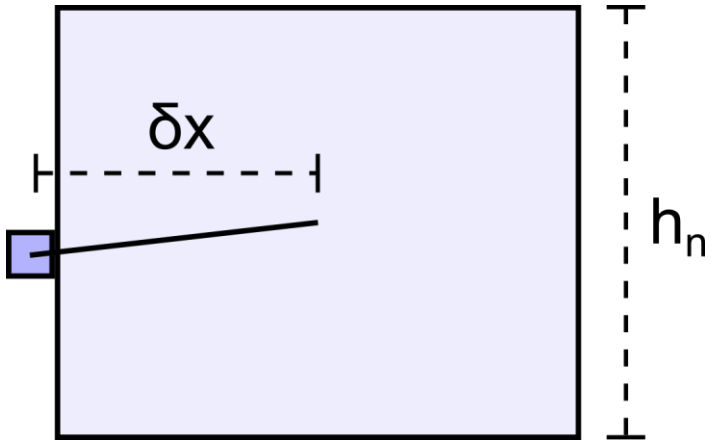
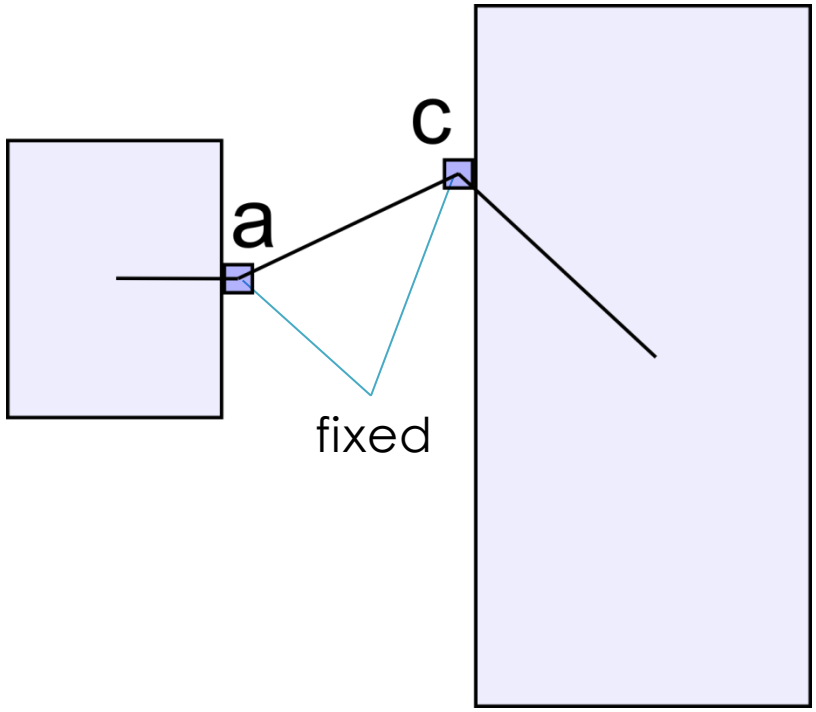


$$x_p + \delta x = x_n$$

$$y_p + \frac{h_n}{2} \geq y_n$$

$$y_p - \frac{h_n}{2} \leq y_n$$

R3 - Orthogonalizing Constraints



[Kieffer et al. GD'13]

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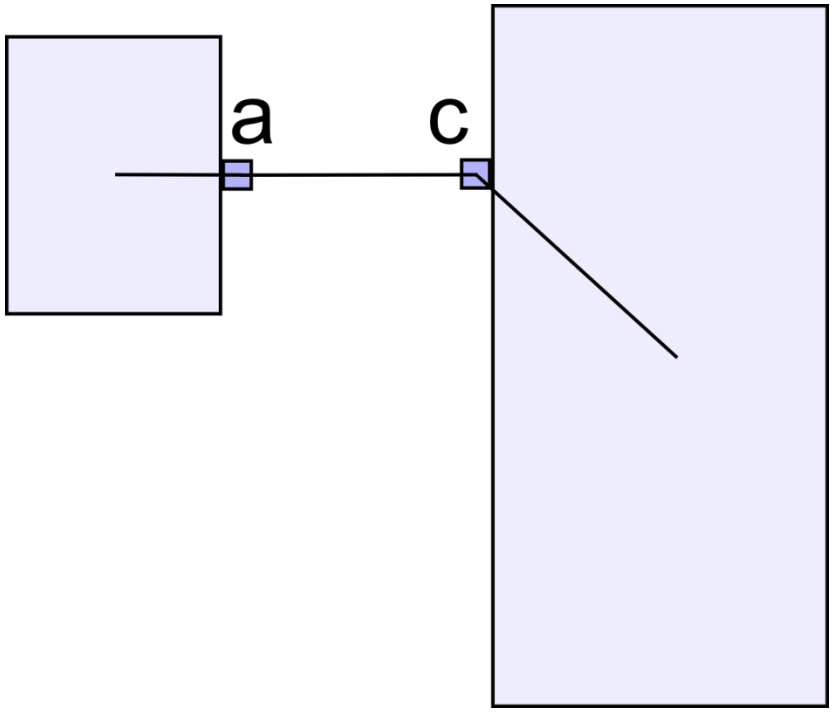

$$y_a = y_c$$

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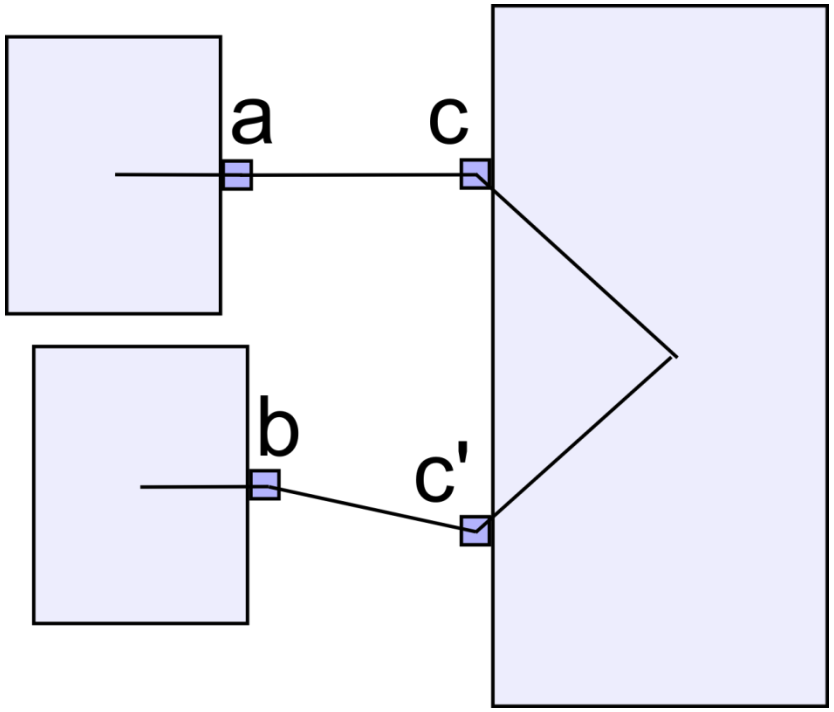

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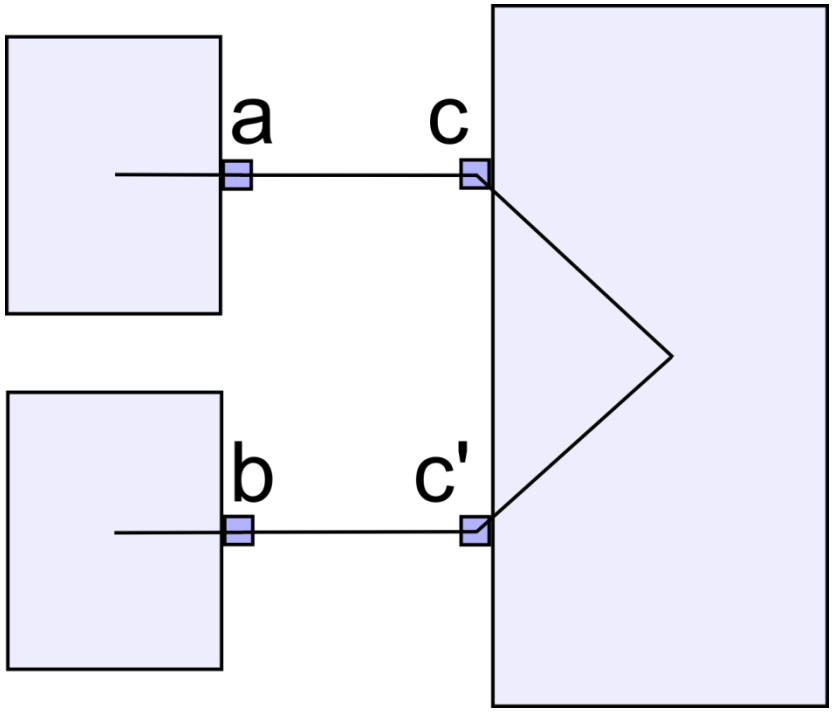
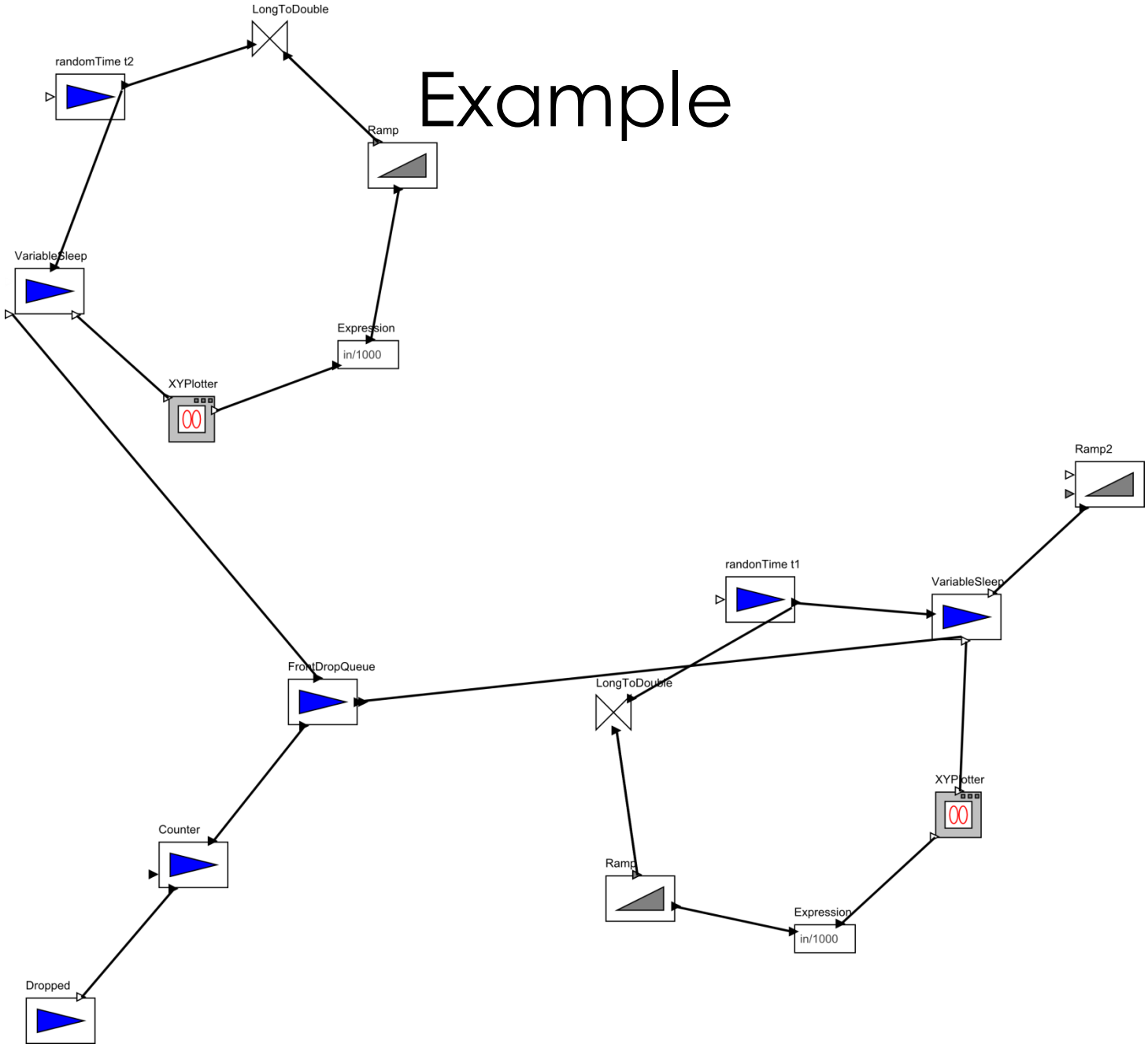


$$y_a = y_c$$

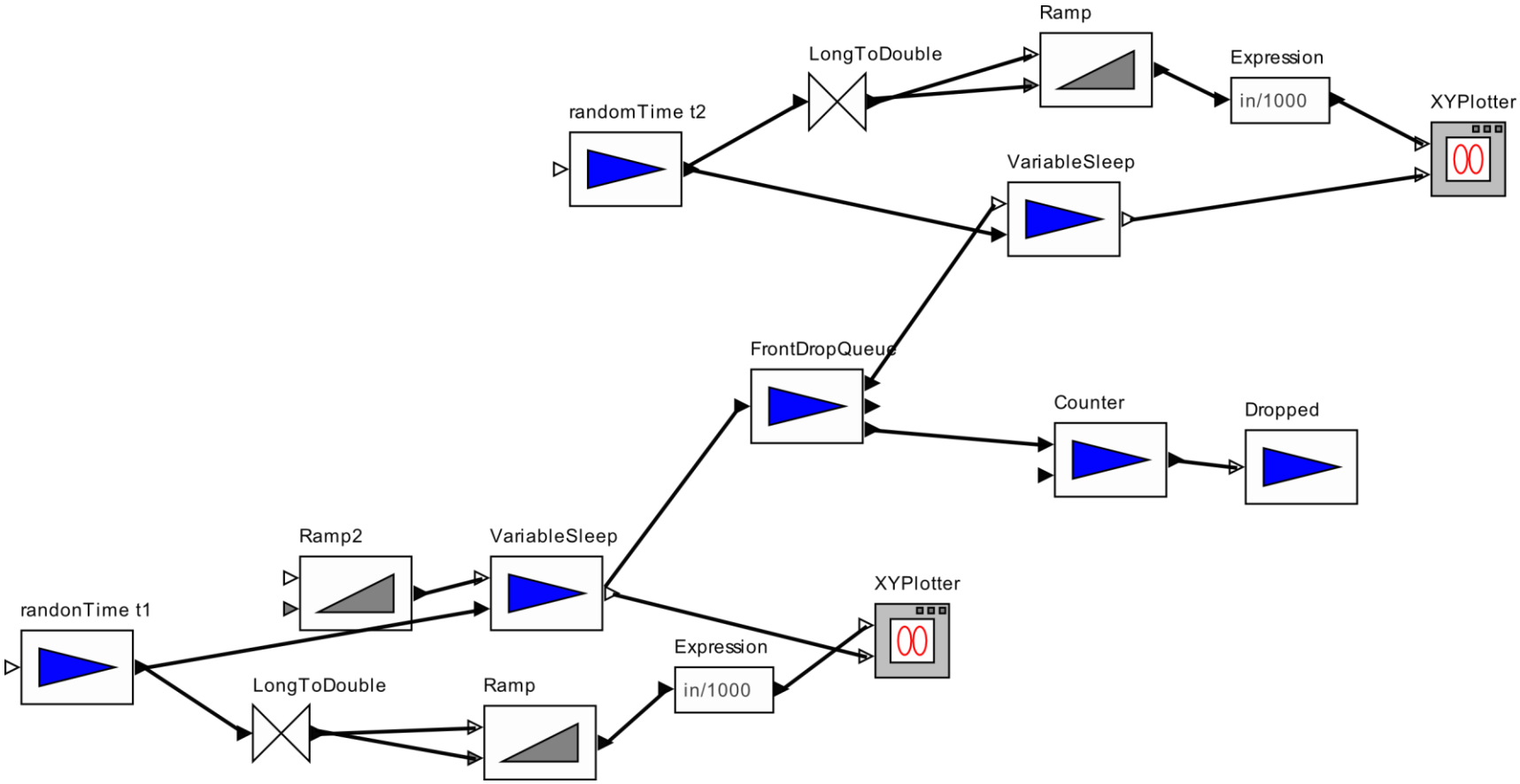
$$y_b = y_{c\prime}$$

[Kieffer et al. GD'13]

Example


LongToDouble
randomTime t2
Ramp
VariableSleep
Expression
in/1000
XYPlotter
Ramp2
randonTime t1
VariableSleep
FrontDropQueue
LongToDouble
XYPlotter
Counter
Ramp
Expression
in/1000
Dropped

Example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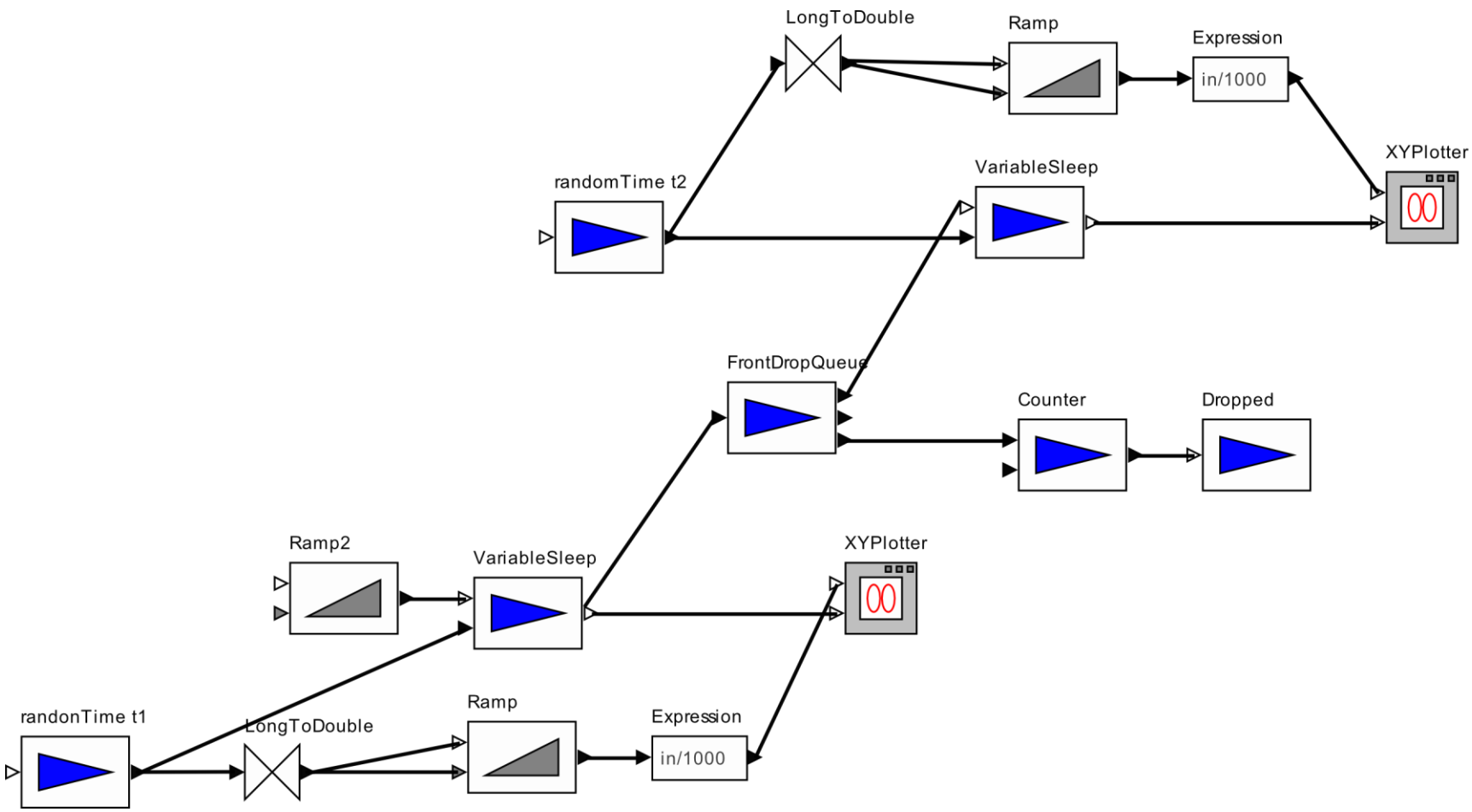
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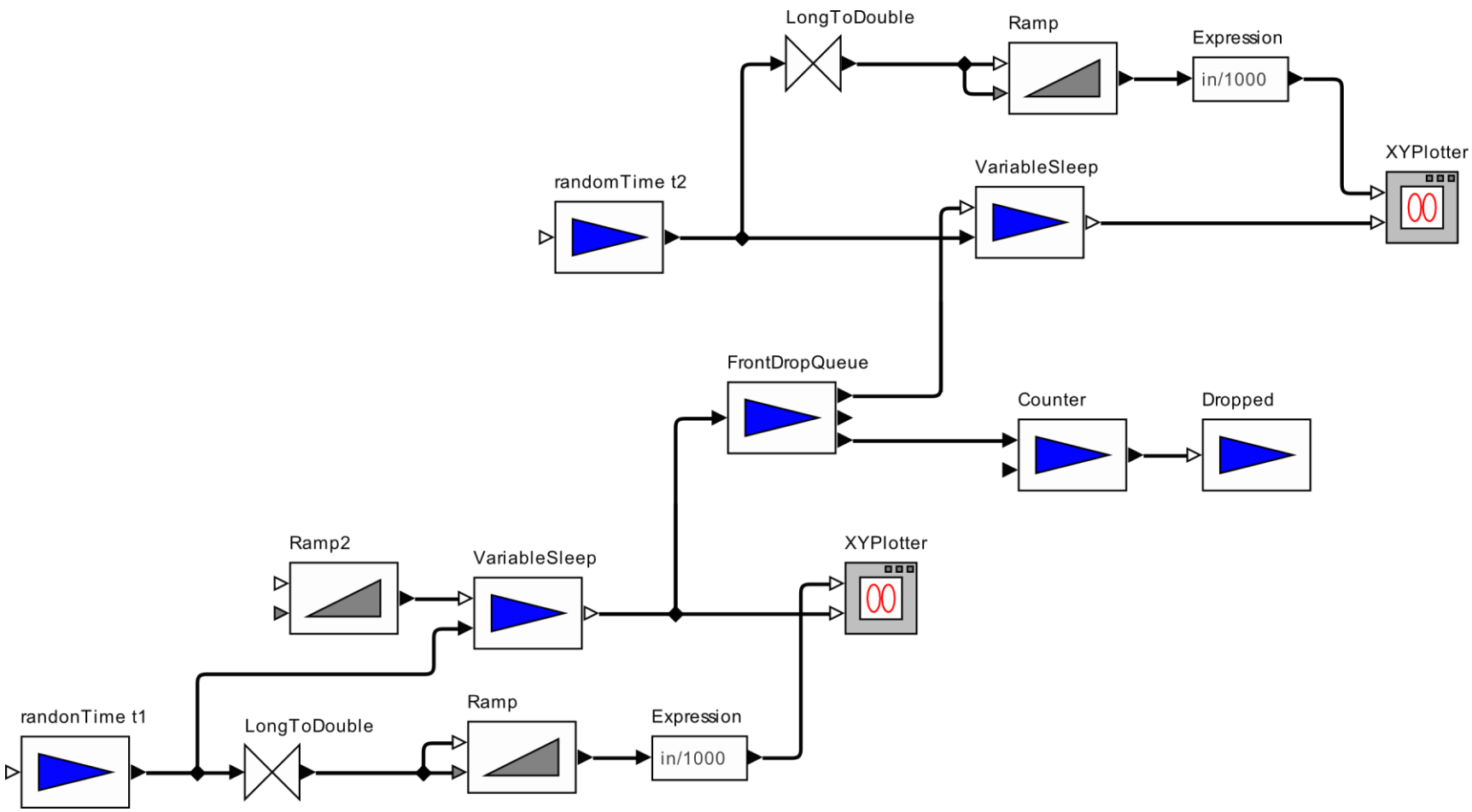

[Wybrow et al. GD'10]

Results

Compared to current approach (KLay Layered)

Results

Compared to current approach (KLay Layered)

BETTER

Stress

Results

Compared to current approach (KLay Layered)

BETTER

Stress

Average edge length

Results

Compared to current approach (KLay Layered)

BETTER

Stress
Average edge length
Edge length variance

Results

Compared to current approach (KLay Layered)

BETTER

Stress
Average edge length
Edge length variance
Area and aspect ratio

Results

Compared to current approach (KLay Layered)

BETTER

Stress
Average edge length
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Symmetry

Results

Compared to current approach (KLay Layered)

BETTER

Stress
Average edge length
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Implementation complexity

Results

Compared to current approach (KLay Layered)

BETTER	WORSE
Stress	Edge crossings
Average edge length	
Edge length variance	
Area and aspect ratio	
Symmetry	
Implementation complexity	

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Compared to current approach (KLay Layered)

BETTER	WORSE
Stress	Edge crossings
Average edge length	Edge bends
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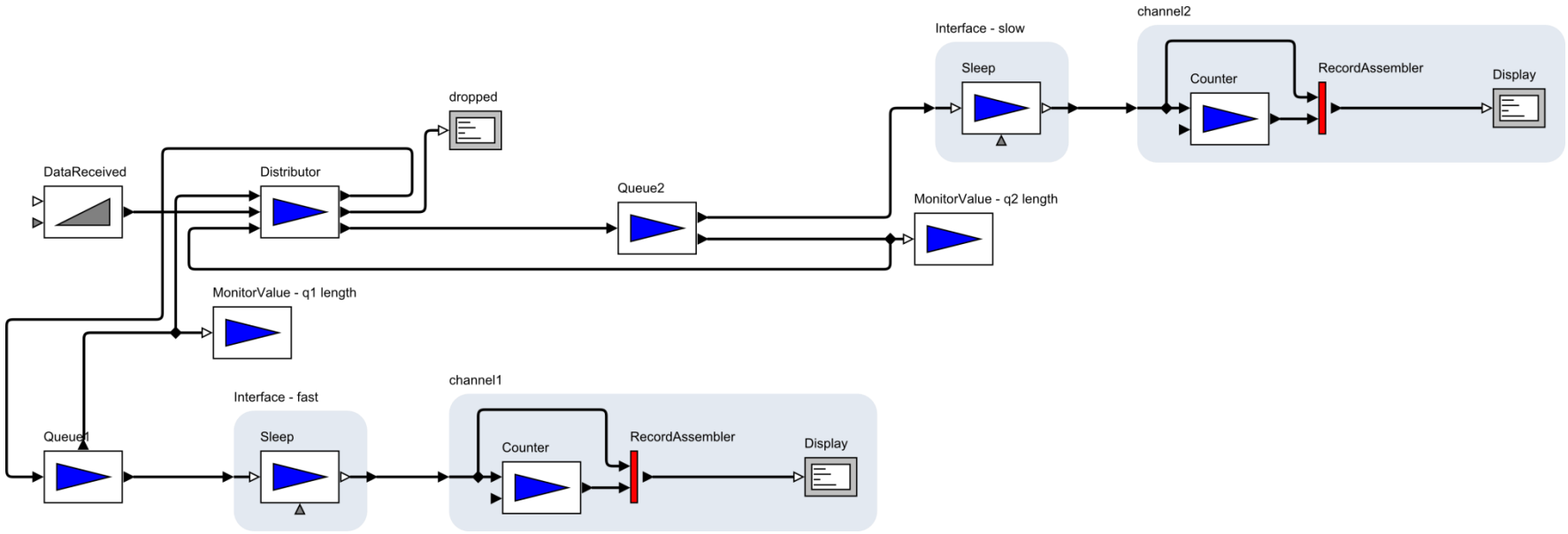
Symmetry	
Implementation complexity	

Results

Compared to current approach (KLay Layered)

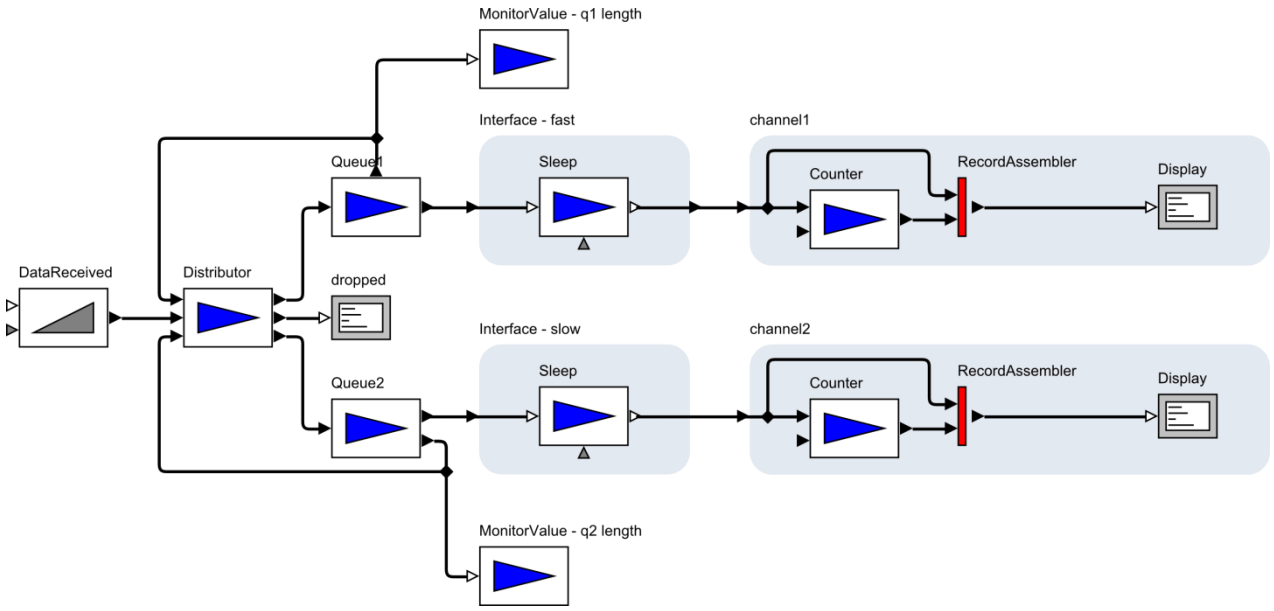
BETTER	WORSE
Stress	Edge crossings
Average edge length	Edge bends
Edge length variance	
Area and aspect ratio	
Symmetry	
Implementation complexity	Execution time

R4/R5 - Compound Graphs



KLay Layered

R4/R5 - Compound Graphs



CoDaFlow

Summary - CoDaFlow

- One goal function: minimize stress

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  2. + Flow constraints
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  4. + Non-overlap constraints
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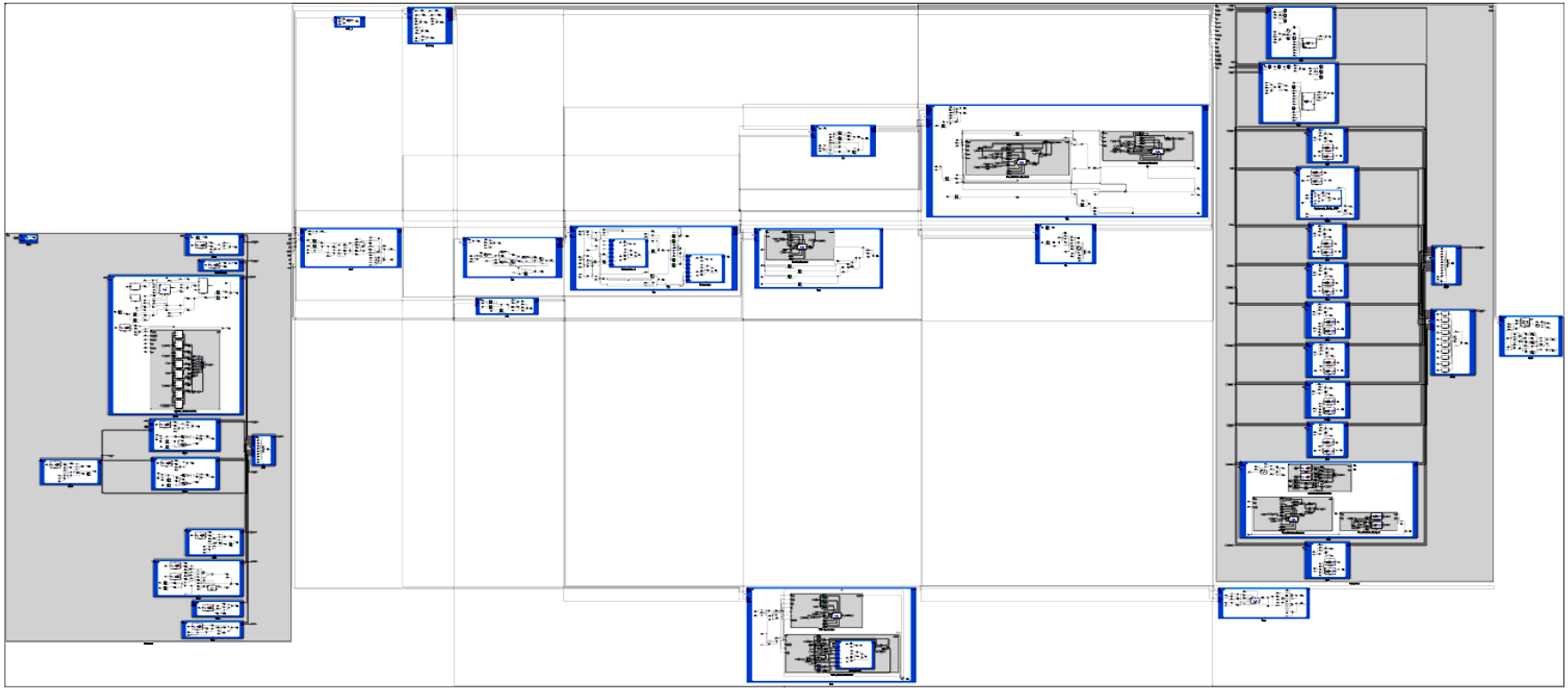
  4. + Non-overlap constraints
  5. + Orthogonalizing constraints
- Orthogonal edge routing with given node positions

Closer to Industrial Scale



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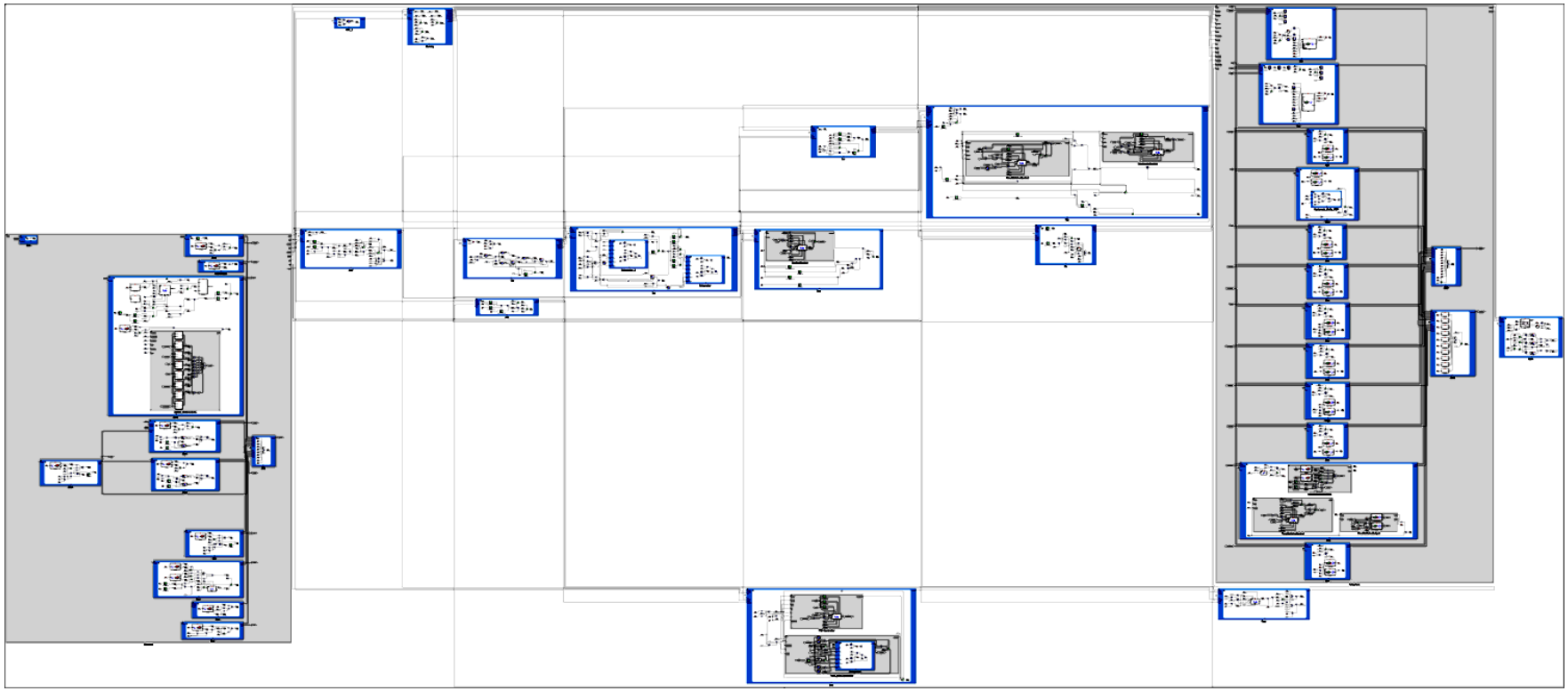

Thank you! Questions?

References

- Schulze, C. D., Spönemann, M., & von Hanxleden, R. (2014). Drawing layered graphs with port constraints. *Journal of Visual Languages & Computing*.
- Dwyer, T., Koren, Y., & Marriott, K. (2006). IPSep-CoLa: An incremental procedure for separation constraint layout of graphs. *IEEE Transactions on Visualization and Computer Graphics*
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- Wybrow, M., Marriott, K., & Stuckey, P. (2010). Orthogonal connector routing. *Graph Drawing*.