Overview of PhD Work

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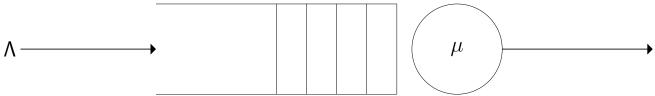
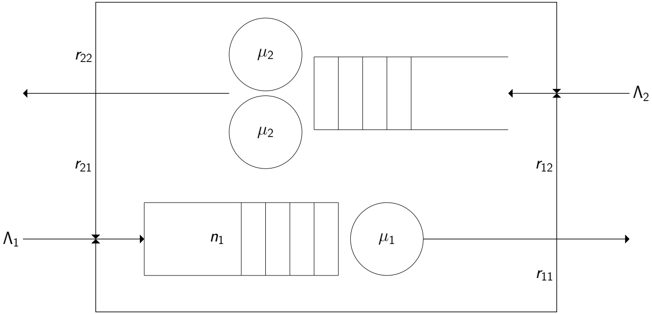
What is a Queue?



What is a Queue?



Simulation with Ciw

Open Source Python Library

@CiwPython
https://github.com/geraintpalmer/Ciw
https://pypi.python.org/pypi/Ciw
http://ciw.readthedocs.io

```
>>> params = {'Arrival_distributions': [['Exponential', 6.0],
...                                     ['Triangular', 0.05, 0.8, 0.9]]
...           'Service_distributions': [['Weibull', 0.8, 0.9],
...                                     ['Lognormal', 4.5, 2.0]],
...           'Transition_matrices': [[0.0, 0.6],
...                                   [0.3, 0.1]],
...           'Number_of_servers': [4, 'Inf']}
```

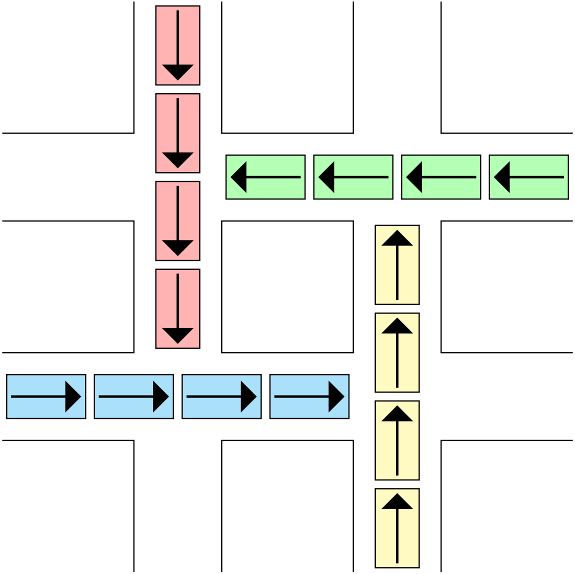
```
>>> import ciw
>>> ciw.seed(6)
>>> N = ciw.create_network(params)
>>> Q = ciw.Simulation(N)
>>> Q.simulate_until_max_time(2000)
>>> recs = Q.get_all_records()
```

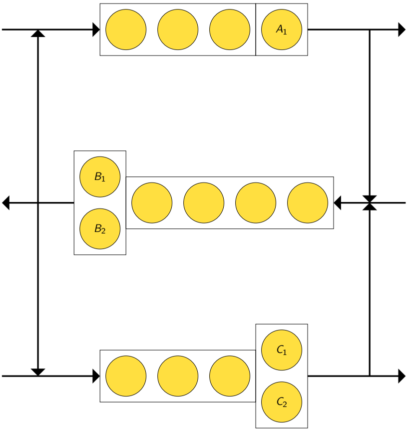
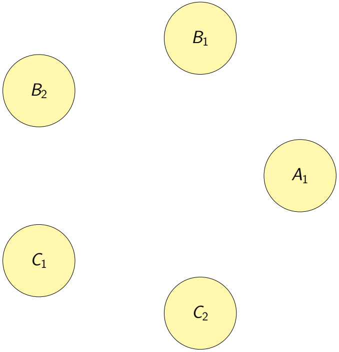
Visualising Ciw Data

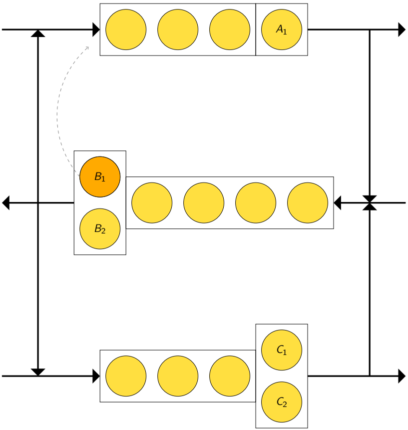
CiwVis

https://github.com/CiwPython/CiwVis

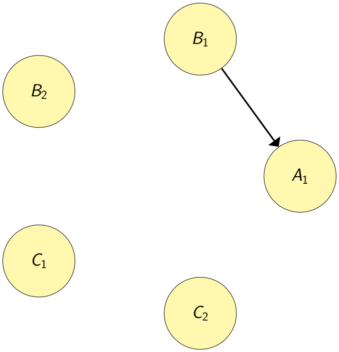
Deadlock



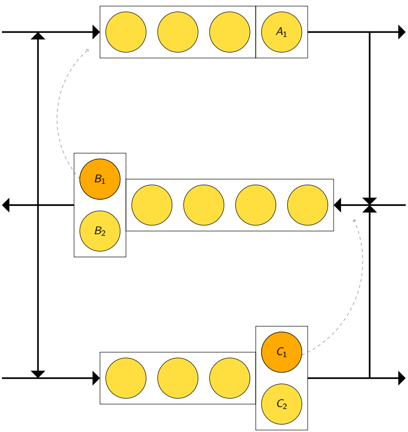

A_1
B_1
B_2
C_1
C_2

B_1
B_2
A_1
C_1
C_2



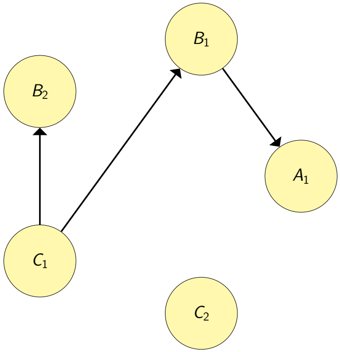
A1
B1
B2
C1
C2



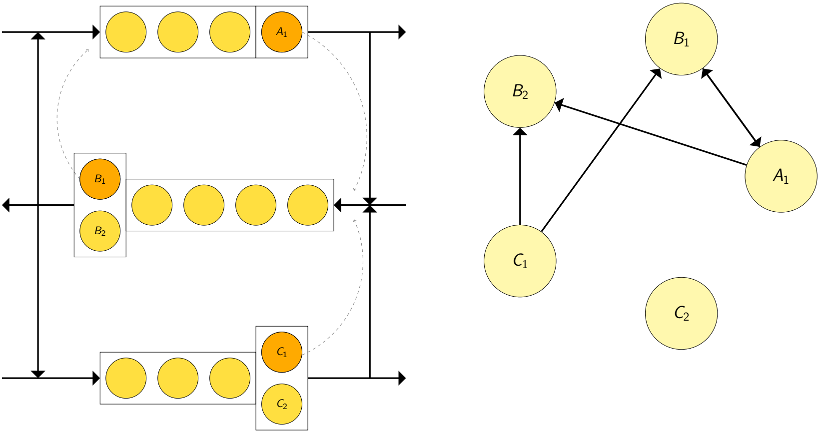
B1
B2
A1
C1
C2

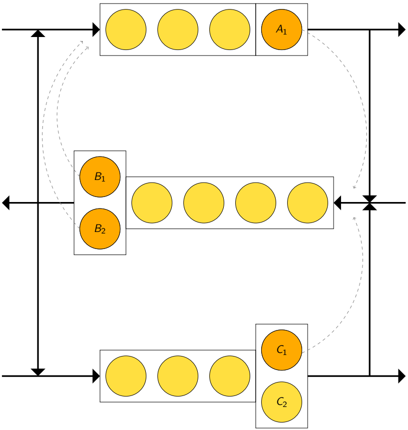


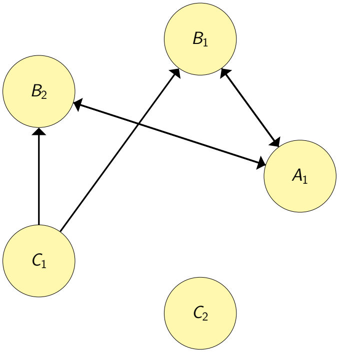
A_1
B_1
B_2
C_1
C_2

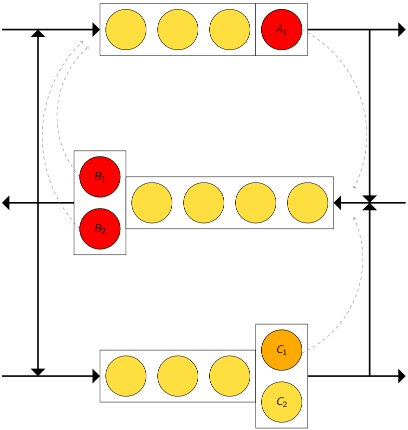


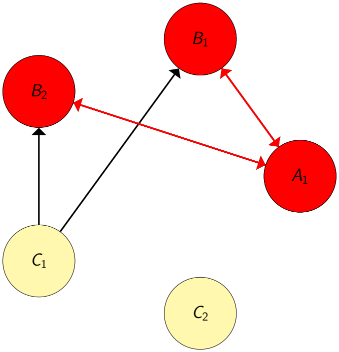
B_1
B_2
A_1
C_1
C_2


A_1
B_1
B_2
C_1
C_2
B_1
B_2
A_1
C_1
C_2

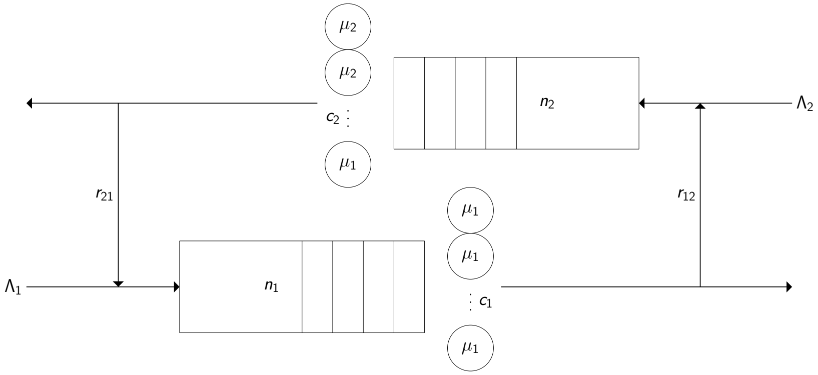

A_1
B_1
B_2
C_1
C_2


B_1
B_2
A_1
C_1
C_2


A_1
B_1
B_2
C_1
C_2


B_1
B_2
A_1
C_1
C_2

Markovian Model of Deadlock

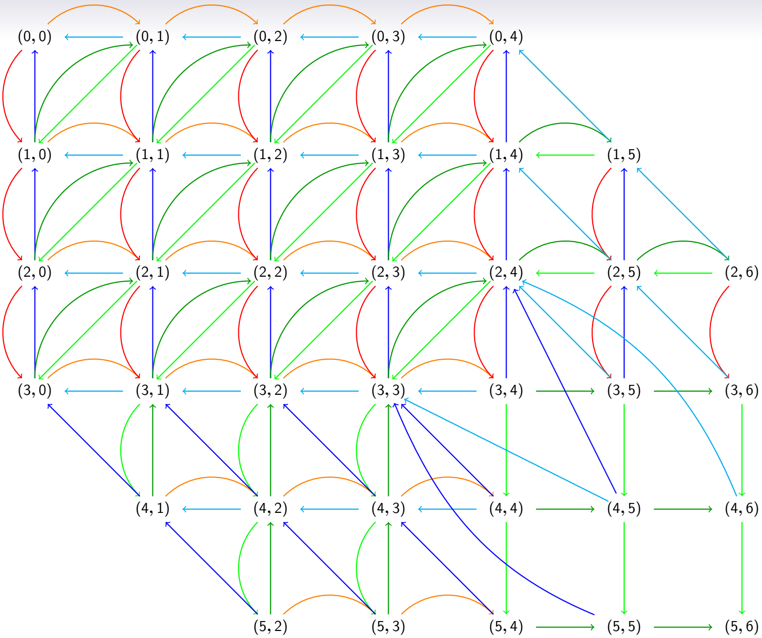


$$(i, j)$$

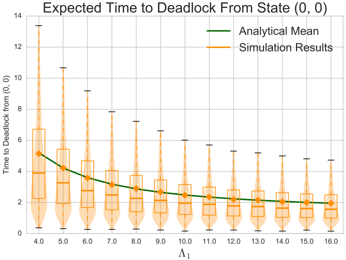
$$S = \{(i,j) \in \mathbb{N}^{(n_1+c_1+c_2)\times(n_2+c_2+c_1)} \mid i \leq n_1 + c_1 + j,\ j \leq n_2 + c_2 + i\}$$

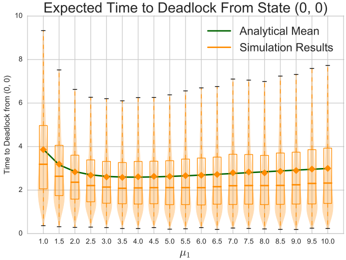
$$\begin{aligned}
\delta &= (i_2, j_2) - (i_1, j_1) \\
b_1 &= \max(0, i_1 - n_1 - c_1) \\
b_2 &= \max(0, i_2 - n_2 - c_2) \\
s_1 &= \min(i_1, c_1) - b_2 \\
s_2 &= \min(i_2, c_2) - b_1
\end{aligned}$$

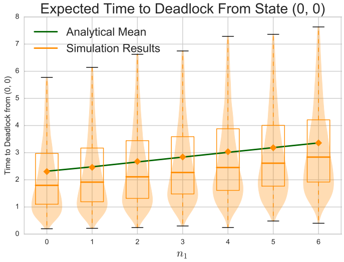
	$j_1 < n_2 + c_2$	$j_1 = n_2 + c_2$	$j_1 > n_2 + c_2$
$i_1 < n_1 + c_1$	Λ_1 if $\delta = (1,0)$ Λ_2 if $\delta = (0,1)$ $r_{12}s_1\mu_1$ if $\delta = (-1,1)$ $r_{21}s_2\mu_2$ if $\delta = (1,-1)$ $(1-r_{12})s_1\mu_1$ if $\delta = (-1,0)$ $(1-r_{21})s_2\mu_2$ if $\delta = (0,-1)$	Λ_1 if $\delta = (1,0)$ $r_{12}s_1\mu_1$ if $\delta = (0,1)$ $r_{21}s_2\mu_2$ if $\delta = (1,-1)$ $(1-r_{12})s_1\mu_1$ if $\delta = (-1,0)$ $(1-r_{21})s_2\mu_2$ if $\delta = (0,-1)$	Λ_1 if $\delta = (1,0)$ $r_{12}s_1\mu_1$ if $\delta = (0,1)$ $r_{21}s_2\mu_2$ if $\delta = (0,-1)$ $(1-r_{12})s_1\mu_1$ if $\delta = (-1,0)$ $(1-r_{21})s_2\mu_2$ if $\delta = (-1,-1)$
$i_1 = n_1 + c_1$	Λ_2 if $\delta = (0,1)$ $r_{12}s_1\mu_1$ if $\delta = (-1,1)$ $r_{21}s_2\mu_2$ if $\delta = (1,0)$ $(1-r_{12})s_1\mu_1$ if $\delta = (-1,0)$ $(1-r_{21})s_2\mu_2$ if $\delta = (0,-1)$	$r_{12}s_1\mu_1$ if $\delta = (0,1)$ $r_{21}s_2\mu_2$ if $\delta = (1,0)$ $(1-r_{12})s_1\mu_1$ if $\delta = (-1,0)$ $(1-r_{21})s_2\mu_2$ if $\delta = (0,-1)$	$r_{12}s_1\mu_1$ if $\delta = (0,1)$ $r_{21}s_2\mu_2$ if $\delta = (1,0)$ $(1-r_{12})s_1\mu_1$ if $\delta = (-1,0)$ $(1-r_{21})s_2\mu_2$ if $\delta = (-1,-1)$
$i_1 > n_1 + c_1$	Λ_2 if $\delta = (0,1)$ $r_{12}s_1\mu_1$ if $\delta = (-1,0)$ $r_{21}s_2\mu_2$ if $\delta = (1,0)$ $(1-r_{12})s_1\mu_1$ if $\delta = (-1,-1)$ $(1-r_{21})s_2\mu_2$ if $\delta = (0,-1)$	$r_{12}s_1\mu_1$ if $\delta = (0,1)$ $r_{21}s_2\mu_2$ if $\delta = (1,0)$ $(1-r_{12})s_1\mu_1$ if $\delta = (-1,-1)$ $(1-r_{21})s_2\mu_2$ if $\delta = (0,-1)$	$r_{12}s_1\mu_1$ if $\delta = (0,1)$ $r_{21}s_2\mu_2$ if $\delta = (1,0)$ $(1-r_{12})s_1\mu_1$ if $\delta = (-\min(b_1+1, b_2+1), -\min(b_1, b_2+1))$ $(1-r_{21})s_2\mu_2$ if $\delta = (-\min(b_1+1, b_2), -\min(b_1+1, b_2+1))$

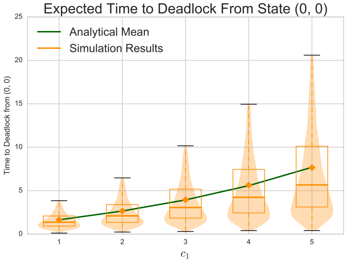

(0, 0) (0, 1) (0, 2) (0, 3) (0, 4)
(1, 0) (1, 1) (1, 2) (1, 3) (1, 4) (1, 5)
(2, 0) (2, 1) (2, 2) (2, 3) (2, 4) (2, 5) (2, 6)
(3, 0) (3, 1) (3, 2) (3, 3) (3, 4) (3, 5) (3, 6)
(4, 1) (4, 2) (4, 3) (4, 4) (4, 5) (4, 6)
(5, 2) (5, 3) (5, 4) (5, 5) (5, 6)

Times to Deadlock

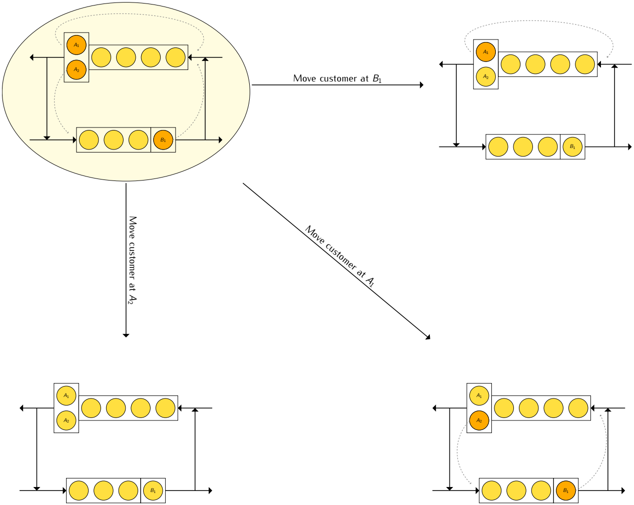




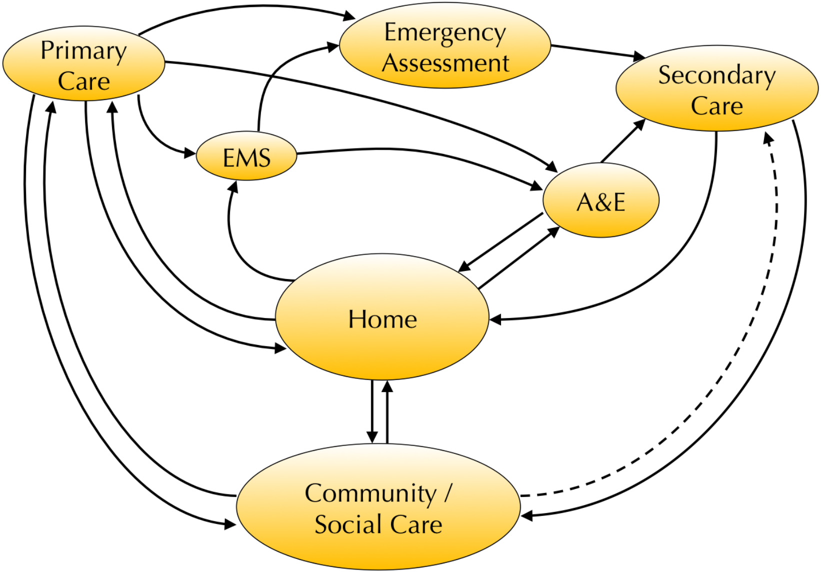




Optimally Resolving Deadlock



OPICP



Primary Care
Emergency Assessment
Secondary Care
EMS
A&E
Home
Community / Social Care

Thank you.