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ЛАБОРАТОРНАЯ РАБОТА №3

«СИНХРОНИЗАЦИЯ ПРОЦЕССОВ»

по дисциплине «Операционные системы»

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1. ЦЕЛЬ РАБОТЫ

Цель работы – изучение примитивов синхронизации и методов работы с ними, решение классической задачи узкого моста и тестирование решения в рамках операционной системы Pintos.

2. ХОД РАБОТЫ

Для решения задачи было принято решение об использование семафоров как основных типов синхронизации. Важно подметить, что на каждый тип машин (приоритет и движение) был создан свой семафор.

В эти семафоры во время пересчета всех машин благодаря функции thread_yield и матрицы cars_counts[2][2] блокировались машины нужного направления. Элементы матрицы же инкрементировались по индексам, равным приоритету и направлению движения автомобиля(массив семафоров работает так же, то есть, например, cars_counts[prio][dir]).

Для контроля проезда машин по мосту был создан семафор bridge_sema. Повышение семафора выбранной машины вытаскивает эту машину(поток) для проезда(выполнения), но при действии sema_down(&bridge_sema) машина записывается в очередь на мост, то есть отправляется на него.

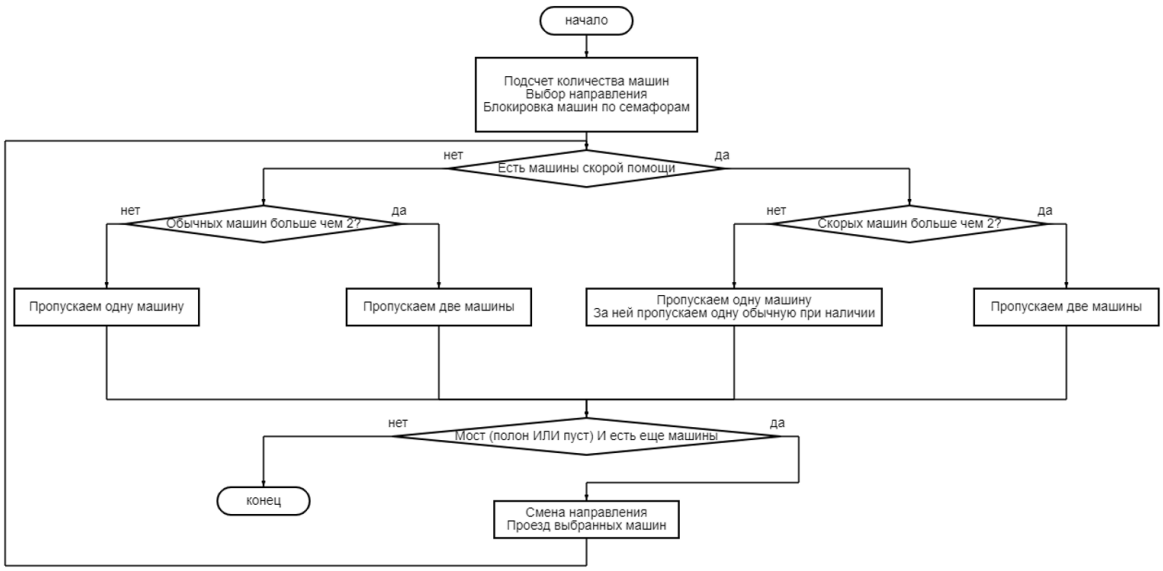
Рассмотрим ключевые функции:

- narrow_bridge_init:
    - Инициализация всех семафоров и изначальных значений переменных
- arrive_bridge:
    - Подсчет количества всех машин
    - Выбор начального направления
    - Блокировка машин в семафоры в зависимости от их типа (приоритет, направление движения)
    - Старт движения
- exit_bridge;

- Уменьшение количества машин определенного типа
- Изменение направления, если мост полон и еще есть машины
- Продвижение машин по мосту (sema_up)
- Выбор новых машин (move_to_bridge)

- move_to_bridge:
  - Рассмотрены все случаи отправки машин: существование двух скорых или обычных машин по направлению, осталась одна скорая по направлению – значит за ней можно послать обычную, если есть, или машин не осталось.

Блок-схема алгоритма выбора машины(процесса) и их взаимодействия представлена ниже:



Как видно из блок-схемы, выбор скорой помощи вне очереди обусловлен расстановкой блоков конструкции if..else if и повышением/понижением семафоров в них(моментальной передачей процесса в список машин, ожидающих заезд на мост - bridge_sema.waiters)

Изменение направления тогда, когда мост полон, позволяет избавиться от ресурсного голодания одной из сторон, например, если на одной стороны намного больше машин скорой помощи, чем на другой.

3. РЕЗУЛЬТАТЫ РАБОТЫ АЛГОРИТМА

```
Boot complete.
Executing 'narrow-bridge 0 0 0 0':
(narrow-bridge) begin
(narrow-bridge) end
Execution of 'narrow-bridge 0 0 0 0' complete.
```

```
Boot complete.
Executing 'narrow-bridge 0 0 0 1':
(narrow-bridge) begin
(narrow-bridge) Vehicle:    1, prio: emer, direct: l <- r, ticks=  44
(narrow-bridge) end
Execution of 'narrow-bridge 0 0 0 1' complete.
```

```
Executing 'narrow-bridge 0 4 0 0':
(narrow-bridge) begin
(narrow-bridge) Vehicle:    4, prio: norm, direct: l <- r, ticks=  42
(narrow-bridge) Vehicle:    1, prio: norm, direct: l <- r, ticks=  43
(narrow-bridge) Vehicle:    3, prio: norm, direct: l <- r, ticks=  55
(narrow-bridge) Vehicle:    2, prio: norm, direct: l <- r, ticks=  55
(narrow-bridge) end
Execution of 'narrow-bridge 0 4 0 0' complete.
```

```
Boot complete.
Executing 'narrow-bridge 0 0 4 0':
(narrow-bridge) begin
(narrow-bridge) Vehicle:    4, prio: emer, direct: l -> r, ticks=  47
(narrow-bridge) Vehicle:    1, prio: emer, direct: l -> r, ticks=  47
(narrow-bridge) Vehicle:    3, prio: emer, direct: l -> r, ticks=  58
(narrow-bridge) Vehicle:    2, prio: emer, direct: l -> r, ticks=  58
(narrow-bridge) end
Execution of 'narrow-bridge 0 0 4 0' complete.
```

```
Executing 'narrow-bridge 3 3 3 3':
(narrow-bridge) begin
(narrow-bridge) Vehicle:    7, prio: emer, direct: l -> r, ticks=  41
(narrow-bridge) Vehicle:    8, prio: emer, direct: l -> r, ticks=  42
(narrow-bridge) Vehicle:   10, prio: emer, direct: l <- r, ticks=  53
(narrow-bridge) Vehicle:   11, prio: emer, direct: l <- r, ticks=  53
(narrow-bridge) Vehicle:    9, prio: emer, direct: l -> r, ticks=  63
(narrow-bridge) Vehicle:    1, prio: norm, direct: l -> r, ticks=  63
(narrow-bridge) Vehicle:   12, prio: emer, direct: l <- r, ticks=  74
(narrow-bridge) Vehicle:    4, prio: norm, direct: l <- r, ticks=  74
(narrow-bridge) Vehicle:    2, prio: norm, direct: l -> r, ticks=  85
(narrow-bridge) Vehicle:    3, prio: norm, direct: l -> r, ticks=  85
(narrow-bridge) Vehicle:    5, prio: norm, direct: l <- r, ticks=  95
(narrow-bridge) Vehicle:    6, prio: norm, direct: l <- r, ticks=  95
(narrow-bridge) end
Execution of 'narrow-bridge 3 3 3 3' complete.
```

```
Executing 'narrow-bridge 4 3 4 3':
(narrow-bridge) begin
(narrow-bridge) Vehicle:    8, prio: emer, direct: l -> r, ticks=  43
(narrow-bridge) Vehicle:    9, prio: emer, direct: l -> r, ticks=  44
(narrow-bridge) Vehicle:   12, prio: emer, direct: l <- r, ticks=  54
(narrow-bridge) Vehicle:   13, prio: emer, direct: l <- r, ticks=  54
(narrow-bridge) Vehicle:   10, prio: emer, direct: l -> r, ticks=  65
(narrow-bridge) Vehicle:   11, prio: emer, direct: l -> r, ticks=  65
(narrow-bridge) Vehicle:   14, prio: emer, direct: l <- r, ticks=  76
(narrow-bridge) Vehicle:    5, prio: norm, direct: l <- r, ticks=  76
(narrow-bridge) Vehicle:    1, prio: norm, direct: l -> r, ticks=  87
(narrow-bridge) Vehicle:    2, prio: norm, direct: l -> r, ticks=  87
(narrow-bridge) Vehicle:    6, prio: norm, direct: l <- r, ticks=  98
(narrow-bridge) Vehicle:    7, prio: norm, direct: l <- r, ticks=  98
(narrow-bridge) Vehicle:    3, prio: norm, direct: l -> r, ticks= 108
(narrow-bridge) Vehicle:    4, prio: norm, direct: l -> r, ticks= 108
(narrow-bridge) end
Execution of 'narrow-bridge 4 3 4 3' complete.
```

```
Executing 'narrow-bridge 7 23 17 1':
(narrow-bridge) begin
(narrow-bridge) Vehicle:   31, prio: emer, direct: l -> r, ticks=  47
(narrow-bridge) Vehicle:   32, prio: emer, direct: l -> r, ticks=  47
(narrow-bridge) Vehicle:   48, prio: emer, direct: l <- r, ticks=  58
(narrow-bridge) Vehicle:    8, prio: norm, direct: l <- r, ticks=  58
(narrow-bridge) Vehicle:   33, prio: emer, direct: l -> r, ticks=  68
(narrow-bridge) Vehicle:   34, prio: emer, direct: l -> r, ticks=  68
(narrow-bridge) Vehicle:   35, prio: emer, direct: l -> r, ticks=  79
(narrow-bridge) Vehicle:   36, prio: emer, direct: l -> r, ticks=  79
(narrow-bridge) Vehicle:   37, prio: emer, direct: l -> r, ticks=  90
(narrow-bridge) Vehicle:   38, prio: emer, direct: l -> r, ticks=  90
(narrow-bridge) Vehicle:   39, prio: emer, direct: l -> r, ticks= 100
(narrow-bridge) Vehicle:   40, prio: emer, direct: l -> r, ticks= 100
(narrow-bridge) Vehicle:   41, prio: emer, direct: l -> r, ticks= 111
(narrow-bridge) Vehicle:   42, prio: emer, direct: l -> r, ticks= 111
(narrow-bridge) Vehicle:   43, prio: emer, direct: l -> r, ticks= 122
(narrow-bridge) Vehicle:   44, prio: emer, direct: l -> r, ticks= 122
(narrow-bridge) Vehicle:   45, prio: emer, direct: l -> r, ticks= 132
(narrow-bridge) Vehicle:   46, prio: emer, direct: l -> r, ticks= 132
(narrow-bridge) Vehicle:   47, prio: emer, direct: l -> r, ticks= 142
(narrow-bridge) Vehicle:    1, prio: norm, direct: l -> r, ticks= 142
(narrow-bridge) Vehicle:    9, prio: norm, direct: l <- r, ticks= 153
(narrow-bridge) Vehicle:   10, prio: norm, direct: l <- r, ticks= 154
(narrow-bridge) Vehicle:    2, prio: norm, direct: l -> r, ticks= 165
(narrow-bridge) Vehicle:    3, prio: norm, direct: l -> r, ticks= 165
(narrow-bridge) Vehicle:   11, prio: norm, direct: l <- r, ticks= 176
(narrow-bridge) Vehicle:   12, prio: norm, direct: l <- r, ticks= 176
(narrow-bridge) Vehicle:    4, prio: norm, direct: l -> r, ticks= 187
(narrow-bridge) Vehicle:    5, prio: norm, direct: l -> r, ticks= 187
(narrow-bridge) Vehicle:   13, prio: norm, direct: l <- r, ticks= 198
(narrow-bridge) Vehicle:   14, prio: norm, direct: l <- r, ticks= 198
(narrow-bridge) Vehicle:    6, prio: norm, direct: l -> r, ticks= 209
(narrow-bridge) Vehicle:    7, prio: norm, direct: l -> r, ticks= 209
(narrow-bridge) Vehicle:   15, prio: norm, direct: l <- r, ticks= 220
(narrow-bridge) Vehicle:   16, prio: norm, direct: l <- r, ticks= 220
(narrow-bridge) Vehicle:   17, prio: norm, direct: l <- r, ticks= 231
(narrow-bridge) Vehicle:   18, prio: norm, direct: l <- r, ticks= 231
(narrow-bridge) Vehicle:   19, prio: norm, direct: l <- r, ticks= 241
(narrow-bridge) Vehicle:   20, prio: norm, direct: l <- r, ticks= 241
(narrow-bridge) Vehicle:   21, prio: norm, direct: l <- r, ticks= 253
(narrow-bridge) Vehicle:   22, prio: norm, direct: l <- r, ticks= 253
(narrow-bridge) Vehicle:   23, prio: norm, direct: l <- r, ticks= 263
(narrow-bridge) Vehicle:   24, prio: norm, direct: l <- r, ticks= 263
(narrow-bridge) Vehicle:   25, prio: norm, direct: l <- r, ticks= 274
(narrow-bridge) Vehicle:   26, prio: norm, direct: l <- r, ticks= 274
(narrow-bridge) Vehicle:   27, prio: norm, direct: l <- r, ticks= 285
(narrow-bridge) Vehicle:   28, prio: norm, direct: l <- r, ticks= 285
(narrow-bridge) Vehicle:   29, prio: norm, direct: l <- r, ticks= 296
(narrow-bridge) Vehicle:   30, prio: norm, direct: l <- r, ticks= 296
(narrow-bridge) end
Execution of 'narrow-bridge 7 23 17 1' complete.
```

```
(narrow-bridge) Vehicle:   12, prio: norm, direct: l -> r, ticks= 154
(narrow-bridge) Vehicle:   51, prio: norm, direct: l <- r, ticks= 164
(narrow-bridge) Vehicle:   52, prio: norm, direct: l <- r, ticks= 164
(narrow-bridge) Vehicle:   13, prio: norm, direct: l -> r, ticks= 175
(narrow-bridge) Vehicle:   14, prio: norm, direct: l -> r, ticks= 175
(narrow-bridge) Vehicle:   53, prio: norm, direct: l <- r, ticks= 186
(narrow-bridge) Vehicle:   54, prio: norm, direct: l <- r, ticks= 186
(narrow-bridge) Vehicle:   15, prio: norm, direct: l -> r, ticks= 197
(narrow-bridge) Vehicle:   16, prio: norm, direct: l -> r, ticks= 198
(narrow-bridge) Vehicle:   55, prio: norm, direct: l <- r, ticks= 208
(narrow-bridge) Vehicle:   56, prio: norm, direct: l <- r, ticks= 209
(narrow-bridge) Vehicle:   17, prio: norm, direct: l -> r, ticks= 220
(narrow-bridge) Vehicle:   18, prio: norm, direct: l -> r, ticks= 221
(narrow-bridge) Vehicle:   57, prio: norm, direct: l <- r, ticks= 232
(narrow-bridge) Vehicle:   58, prio: norm, direct: l <- r, ticks= 232
(narrow-bridge) Vehicle:   19, prio: norm, direct: l -> r, ticks= 245
(narrow-bridge) Vehicle:   20, prio: norm, direct: l -> r, ticks= 245
(narrow-bridge) Vehicle:   59, prio: norm, direct: l <- r, ticks= 256
(narrow-bridge) Vehicle:   60, prio: norm, direct: l <- r, ticks= 256
(narrow-bridge) Vehicle:   21, prio: norm, direct: l -> r, ticks= 267
(narrow-bridge) Vehicle:   22, prio: norm, direct: l -> r, ticks= 267
(narrow-bridge) Vehicle:   61, prio: norm, direct: l <- r, ticks= 278
(narrow-bridge) Vehicle:   62, prio: norm, direct: l <- r, ticks= 278
(narrow-bridge) Vehicle:   23, prio: norm, direct: l -> r, ticks= 290
(narrow-bridge) Vehicle:   24, prio: norm, direct: l -> r, ticks= 290
(narrow-bridge) Vehicle:   63, prio: norm, direct: l <- r, ticks= 301
(narrow-bridge) Vehicle:   64, prio: norm, direct: l <- r, ticks= 301
(narrow-bridge) Vehicle:   25, prio: norm, direct: l -> r, ticks= 312
(narrow-bridge) Vehicle:   26, prio: norm, direct: l -> r, ticks= 313
(narrow-bridge) Vehicle:   65, prio: norm, direct: l <- r, ticks= 324
(narrow-bridge) Vehicle:   66, prio: norm, direct: l <- r, ticks= 324
(narrow-bridge) Vehicle:   27, prio: norm, direct: l -> r, ticks= 335
(narrow-bridge) Vehicle:   28, prio: norm, direct: l -> r, ticks= 335
(narrow-bridge) Vehicle:   67, prio: norm, direct: l <- r, ticks= 346
(narrow-bridge) Vehicle:   68, prio: norm, direct: l <- r, ticks= 346
(narrow-bridge) Vehicle:   29, prio: norm, direct: l -> r, ticks= 357
(narrow-bridge) Vehicle:   30, prio: norm, direct: l -> r, ticks= 357
(narrow-bridge) Vehicle:   69, prio: norm, direct: l <- r, ticks= 367
(narrow-bridge) Vehicle:   70, prio: norm, direct: l <- r, ticks= 367
(narrow-bridge) Vehicle:   31, prio: norm, direct: l -> r, ticks= 377
(narrow-bridge) Vehicle:   32, prio: norm, direct: l -> r, ticks= 377
(narrow-bridge) Vehicle:   33, prio: norm, direct: l -> r, ticks= 387
(narrow-bridge) Vehicle:   34, prio: norm, direct: l -> r, ticks= 387
(narrow-bridge) Vehicle:   35, prio: norm, direct: l -> r, ticks= 398
(narrow-bridge) Vehicle:   36, prio: norm, direct: l -> r, ticks= 398
(narrow-bridge) Vehicle:   37, prio: norm, direct: l -> r, ticks= 409
(narrow-bridge) Vehicle:   38, prio: norm, direct: l -> r, ticks= 409
(narrow-bridge) Vehicle:   39, prio: norm, direct: l -> r, ticks= 419
(narrow-bridge) Vehicle:   40, prio: norm, direct: l -> r, ticks= 419
(narrow-bridge) end
Execution of 'narrow-bridge 40 30 0 0' complete.
Timer: 430 ticks
```

```
(narrow-bridge) Vehicle:   12, prio: norm, direct: l -> r, ticks= 170
(narrow-bridge) Vehicle:   43, prio: norm, direct: l <- r, ticks= 181
(narrow-bridge) Vehicle:   44, prio: norm, direct: l <- r, ticks= 182
(narrow-bridge) Vehicle:   13, prio: norm, direct: l -> r, ticks= 193
(narrow-bridge) Vehicle:   14, prio: norm, direct: l -> r, ticks= 193
(narrow-bridge) Vehicle:   45, prio: norm, direct: l <- r, ticks= 204
(narrow-bridge) Vehicle:   46, prio: norm, direct: l <- r, ticks= 204
(narrow-bridge) Vehicle:   15, prio: norm, direct: l -> r, ticks= 215
(narrow-bridge) Vehicle:   16, prio: norm, direct: l -> r, ticks= 215
(narrow-bridge) Vehicle:   47, prio: norm, direct: l <- r, ticks= 226
(narrow-bridge) Vehicle:   48, prio: norm, direct: l <- r, ticks= 227
(narrow-bridge) Vehicle:   17, prio: norm, direct: l -> r, ticks= 238
(narrow-bridge) Vehicle:   18, prio: norm, direct: l -> r, ticks= 239
(narrow-bridge) Vehicle:   49, prio: norm, direct: l <- r, ticks= 250
(narrow-bridge) Vehicle:   50, prio: norm, direct: l <- r, ticks= 250
(narrow-bridge) Vehicle:   19, prio: norm, direct: l -> r, ticks= 261
(narrow-bridge) Vehicle:   20, prio: norm, direct: l -> r, ticks= 261
(narrow-bridge) Vehicle:   51, prio: norm, direct: l <- r, ticks= 272
(narrow-bridge) Vehicle:   52, prio: norm, direct: l <- r, ticks= 272
(narrow-bridge) Vehicle:   21, prio: norm, direct: l -> r, ticks= 283
(narrow-bridge) Vehicle:   22, prio: norm, direct: l -> r, ticks= 283
(narrow-bridge) Vehicle:   53, prio: norm, direct: l <- r, ticks= 294
(narrow-bridge) Vehicle:   54, prio: norm, direct: l <- r, ticks= 294
(narrow-bridge) Vehicle:   23, prio: norm, direct: l -> r, ticks= 305
(narrow-bridge) Vehicle:   24, prio: norm, direct: l -> r, ticks= 305
(narrow-bridge) Vehicle:   55, prio: norm, direct: l <- r, ticks= 316
(narrow-bridge) Vehicle:   56, prio: norm, direct: l <- r, ticks= 317
(narrow-bridge) Vehicle:   25, prio: norm, direct: l -> r, ticks= 327
(narrow-bridge) Vehicle:   26, prio: norm, direct: l -> r, ticks= 327
(narrow-bridge) Vehicle:   57, prio: norm, direct: l <- r, ticks= 339
(narrow-bridge) Vehicle:   58, prio: norm, direct: l <- r, ticks= 340
(narrow-bridge) Vehicle:   27, prio: norm, direct: l -> r, ticks= 351
(narrow-bridge) Vehicle:   28, prio: norm, direct: l -> r, ticks= 351
(narrow-bridge) Vehicle:   59, prio: norm, direct: l <- r, ticks= 362
(narrow-bridge) Vehicle:   60, prio: norm, direct: l <- r, ticks= 362
(narrow-bridge) Vehicle:   29, prio: norm, direct: l -> r, ticks= 373
(narrow-bridge) Vehicle:   30, prio: norm, direct: l -> r, ticks= 373
(narrow-bridge) Vehicle:   61, prio: norm, direct: l <- r, ticks= 384
(narrow-bridge) Vehicle:   62, prio: norm, direct: l <- r, ticks= 384
(narrow-bridge) Vehicle:   63, prio: norm, direct: l <- r, ticks= 396
(narrow-bridge) Vehicle:   64, prio: norm, direct: l <- r, ticks= 396
(narrow-bridge) Vehicle:   65, prio: norm, direct: l <- r, ticks= 407
(narrow-bridge) Vehicle:   66, prio: norm, direct: l <- r, ticks= 407
(narrow-bridge) Vehicle:   67, prio: norm, direct: l <- r, ticks= 418
(narrow-bridge) Vehicle:   68, prio: norm, direct: l <- r, ticks= 418
(narrow-bridge) Vehicle:   69, prio: norm, direct: l <- r, ticks= 429
(narrow-bridge) Vehicle:   32, prio: norm, direct: l <- r, ticks= 429
(narrow-bridge) end
Execution of 'narrow-bridge 30 40 0 0' complete.
Timer: 440 ticks
```

```
Executing 'narrow-bridge 23 23 1 11':
(narrow-bridge) begin
(narrow-bridge) Vehicle:   58, prio: emer, direct: l <- r, ticks=  45
(narrow-bridge) Vehicle:   48, prio: emer, direct: l <- r, ticks=  46
(narrow-bridge) Vehicle:   47, prio: emer, direct: l -> r, ticks=  57
(narrow-bridge) Vehicle:    1, prio: norm, direct: l -> r, ticks=  57
(narrow-bridge) Vehicle:   50, prio: emer, direct: l <- r, ticks=  68
(narrow-bridge) Vehicle:   51, prio: emer, direct: l <- r, ticks=  68
(narrow-bridge) Vehicle:   52, prio: emer, direct: l <- r, ticks=  79
(narrow-bridge) Vehicle:   53, prio: emer, direct: l <- r, ticks=  79
(narrow-bridge) Vehicle:   54, prio: emer, direct: l <- r, ticks=  90
(narrow-bridge) Vehicle:   55, prio: emer, direct: l <- r, ticks=  90
(narrow-bridge) Vehicle:   56, prio: emer, direct: l <- r, ticks= 101
(narrow-bridge) Vehicle:   57, prio: emer, direct: l <- r, ticks= 101
(narrow-bridge) Vehicle:   49, prio: emer, direct: l <- r, ticks= 111
(narrow-bridge) Vehicle:   24, prio: norm, direct: l <- r, ticks= 112
(narrow-bridge) Vehicle:    2, prio: norm, direct: l -> r, ticks= 123
(narrow-bridge) Vehicle:    3, prio: norm, direct: l -> r, ticks= 123
(narrow-bridge) Vehicle:   25, prio: norm, direct: l <- r, ticks= 133
(narrow-bridge) Vehicle:   26, prio: norm, direct: l <- r, ticks= 133
(narrow-bridge) Vehicle:    4, prio: norm, direct: l -> r, ticks= 144
(narrow-bridge) Vehicle:    5, prio: norm, direct: l -> r, ticks= 144
(narrow-bridge) Vehicle:   27, prio: norm, direct: l <- r, ticks= 155
(narrow-bridge) Vehicle:   28, prio: norm, direct: l <- r, ticks= 155
(narrow-bridge) Vehicle:    6, prio: norm, direct: l -> r, ticks= 166
(narrow-bridge) Vehicle:    7, prio: norm, direct: l -> r, ticks= 166
(narrow-bridge) Vehicle:   29, prio: norm, direct: l <- r, ticks= 176
(narrow-bridge) Vehicle:   30, prio: norm, direct: l <- r, ticks= 177
(narrow-bridge) Vehicle:    8, prio: norm, direct: l -> r, ticks= 188
(narrow-bridge) Vehicle:    9, prio: norm, direct: l -> r, ticks= 188
(narrow-bridge) Vehicle:   31, prio: norm, direct: l <- r, ticks= 198
(narrow-bridge) Vehicle:   32, prio: norm, direct: l <- r, ticks= 198
(narrow-bridge) Vehicle:   10, prio: norm, direct: l -> r, ticks= 209
(narrow-bridge) Vehicle:   11, prio: norm, direct: l -> r, ticks= 209
(narrow-bridge) Vehicle:   33, prio: norm, direct: l <- r, ticks= 220
(narrow-bridge) Vehicle:   34, prio: norm, direct: l <- r, ticks= 220
(narrow-bridge) Vehicle:   12, prio: norm, direct: l -> r, ticks= 232
(narrow-bridge) Vehicle:   13, prio: norm, direct: l -> r, ticks= 232
(narrow-bridge) Vehicle:   35, prio: norm, direct: l <- r, ticks= 243
(narrow-bridge) Vehicle:   36, prio: norm, direct: l <- r, ticks= 243
(narrow-bridge) Vehicle:   14, prio: norm, direct: l -> r, ticks= 254
(narrow-bridge) Vehicle:   15, prio: norm, direct: l -> r, ticks= 254
(narrow-bridge) Vehicle:   37, prio: norm, direct: l <- r, ticks= 264
(narrow-bridge) Vehicle:   38, prio: norm, direct: l <- r, ticks= 264
(narrow-bridge) Vehicle:   16, prio: norm, direct: l -> r, ticks= 275
(narrow-bridge) Vehicle:   17, prio: norm, direct: l -> r, ticks= 275
(narrow-bridge) Vehicle:   39, prio: norm, direct: l <- r, ticks= 285
(narrow-bridge) Vehicle:   40, prio: norm, direct: l <- r, ticks= 285
(narrow-bridge) Vehicle:   18, prio: norm, direct: l -> r, ticks= 296
(narrow-bridge) Vehicle:   19, prio: norm, direct: l -> r, ticks= 296
(narrow-bridge) Vehicle:   41, prio: norm, direct: l <- r, ticks= 307
(narrow-bridge) Vehicle:   42, prio: norm, direct: l <- r, ticks= 307
```

```
Boot complete.
Executing 'narrow-bridge 22 22 10 10':
(narrow-bridge) begin
(narrow-bridge) Vehicle:   45, prio: emer, direct: l -> r, ticks=  45
(narrow-bridge) Vehicle:   46, prio: emer, direct: l -> r, ticks=  45
(narrow-bridge) Vehicle:   55, prio: emer, direct: l <- r, ticks=  56
(narrow-bridge) Vehicle:   56, prio: emer, direct: l <- r, ticks=  56
(narrow-bridge) Vehicle:   47, prio: emer, direct: l -> r, ticks=  67
(narrow-bridge) Vehicle:   48, prio: emer, direct: l -> r, ticks=  67
(narrow-bridge) Vehicle:   57, prio: emer, direct: l <- r, ticks=  77
(narrow-bridge) Vehicle:   58, prio: emer, direct: l <- r, ticks=  77
(narrow-bridge) Vehicle:   49, prio: emer, direct: l -> r, ticks=  88
(narrow-bridge) Vehicle:   50, prio: emer, direct: l -> r, ticks=  88
(narrow-bridge) Vehicle:   59, prio: emer, direct: l <- r, ticks=  99
(narrow-bridge) Vehicle:   60, prio: emer, direct: l <- r, ticks=  99
(narrow-bridge) Vehicle:   51, prio: emer, direct: l -> r, ticks= 110
(narrow-bridge) Vehicle:   52, prio: emer, direct: l -> r, ticks= 110
(narrow-bridge) Vehicle:   61, prio: emer, direct: l <- r, ticks= 121
(narrow-bridge) Vehicle:   62, prio: emer, direct: l <- r, ticks= 121
(narrow-bridge) Vehicle:   53, prio: emer, direct: l -> r, ticks= 131
(narrow-bridge) Vehicle:   54, prio: emer, direct: l -> r, ticks= 131
(narrow-bridge) Vehicle:   63, prio: emer, direct: l <- r, ticks= 142
(narrow-bridge) Vehicle:   64, prio: emer, direct: l <- r, ticks= 142
(narrow-bridge) Vehicle:    1, prio: norm, direct: l -> r, ticks= 152
(narrow-bridge) Vehicle:    2, prio: norm, direct: l -> r, ticks= 152
(narrow-bridge) Vehicle:   23, prio: norm, direct: l <- r, ticks= 163
(narrow-bridge) Vehicle:   24, prio: norm, direct: l <- r, ticks= 164
(narrow-bridge) Vehicle:    3, prio: norm, direct: l -> r, ticks= 174
(narrow-bridge) Vehicle:    4, prio: norm, direct: l -> r, ticks= 174
```

```
Executing 'narrow-bridge 0 0 11 12':
(narrow-bridge) begin
(narrow-bridge) Vehicle:   23, prio: emer, direct: l <- r, ticks=  47
(narrow-bridge) Vehicle:   12, prio: emer, direct: l <- r, ticks=  47
(narrow-bridge) Vehicle:    1, prio: emer, direct: l -> r, ticks=  58
(narrow-bridge) Vehicle:    2, prio: emer, direct: l -> r, ticks=  58
(narrow-bridge) Vehicle:   14, prio: emer, direct: l <- r, ticks=  69
(narrow-bridge) Vehicle:   15, prio: emer, direct: l <- r, ticks=  69
(narrow-bridge) Vehicle:    3, prio: emer, direct: l -> r, ticks=  80
(narrow-bridge) Vehicle:    4, prio: emer, direct: l -> r, ticks=  80
(narrow-bridge) Vehicle:   16, prio: emer, direct: l <- r, ticks=  90
(narrow-bridge) Vehicle:   17, prio: emer, direct: l <- r, ticks=  90
(narrow-bridge) Vehicle:    5, prio: emer, direct: l -> r, ticks= 101
(narrow-bridge) Vehicle:    6, prio: emer, direct: l -> r, ticks= 101
(narrow-bridge) Vehicle:   18, prio: emer, direct: l <- r, ticks= 111
(narrow-bridge) Vehicle:   19, prio: emer, direct: l <- r, ticks= 111
(narrow-bridge) Vehicle:    7, prio: emer, direct: l -> r, ticks= 122
(narrow-bridge) Vehicle:    8, prio: emer, direct: l -> r, ticks= 122
(narrow-bridge) Vehicle:   20, prio: emer, direct: l <- r, ticks= 134
(narrow-bridge) Vehicle:   21, prio: emer, direct: l <- r, ticks= 134
(narrow-bridge) Vehicle:    9, prio: emer, direct: l -> r, ticks= 145
(narrow-bridge) Vehicle:   10, prio: emer, direct: l -> r, ticks= 145
(narrow-bridge) Vehicle:   22, prio: emer, direct: l <- r, ticks= 156
(narrow-bridge) Vehicle:   13, prio: emer, direct: l <- r, ticks= 156
(narrow-bridge) Vehicle:   11, prio: emer, direct: l -> r, ticks= 167
(narrow-bridge) end
Execution of 'narrow-bridge 0 0 11 12' complete.
```

```
Executing 'narrow-bridge 0 10 0 10':
(narrow-bridge) begin
(narrow-bridge) Vehicle:   20, prio: emer, direct: l <- r, ticks=  46
(narrow-bridge) Vehicle:   11, prio: emer, direct: l <- r, ticks=  46
(narrow-bridge) Vehicle:   13, prio: emer, direct: l <- r, ticks=  57
(narrow-bridge) Vehicle:   14, prio: emer, direct: l <- r, ticks=  57
(narrow-bridge) Vehicle:   15, prio: emer, direct: l <- r, ticks=  68
(narrow-bridge) Vehicle:   16, prio: emer, direct: l <- r, ticks=  69
(narrow-bridge) Vehicle:   17, prio: emer, direct: l <- r, ticks=  79
(narrow-bridge) Vehicle:   18, prio: emer, direct: l <- r, ticks=  79
(narrow-bridge) Vehicle:   19, prio: emer, direct: l <- r, ticks=  90
(narrow-bridge) Vehicle:   12, prio: emer, direct: l <- r, ticks=  90
(narrow-bridge) Vehicle:    1, prio: norm, direct: l <- r, ticks= 101
(narrow-bridge) Vehicle:    2, prio: norm, direct: l <- r, ticks= 102
(narrow-bridge) Vehicle:    3, prio: norm, direct: l <- r, ticks= 112
(narrow-bridge) Vehicle:    4, prio: norm, direct: l <- r, ticks= 112
(narrow-bridge) Vehicle:    5, prio: norm, direct: l <- r, ticks= 123
(narrow-bridge) Vehicle:    6, prio: norm, direct: l <- r, ticks= 124
(narrow-bridge) Vehicle:    7, prio: norm, direct: l <- r, ticks= 134
(narrow-bridge) Vehicle:    8, prio: norm, direct: l <- r, ticks= 135
(narrow-bridge) Vehicle:    9, prio: norm, direct: l <- r, ticks= 145
(narrow-bridge) Vehicle:   10, prio: norm, direct: l <- r, ticks= 146
(narrow-bridge) end
Execution of 'narrow-bridge 0 10 0 10' complete.
Timer: 157 ticks
```

```
Executing 'narrow-bridge 0 10 10 0':
(narrow-bridge) begin
(narrow-bridge) Vehicle:   20, prio: emer, direct: l -> r, ticks=  42
(narrow-bridge) Vehicle:   11, prio: emer, direct: l -> r, ticks=  43
(narrow-bridge) Vehicle:   13, prio: emer, direct: l -> r, ticks=  55
(narrow-bridge) Vehicle:   14, prio: emer, direct: l -> r, ticks=  55
(narrow-bridge) Vehicle:   15, prio: emer, direct: l -> r, ticks=  65
(narrow-bridge) Vehicle:   16, prio: emer, direct: l -> r, ticks=  65
(narrow-bridge) Vehicle:   17, prio: emer, direct: l -> r, ticks=  75
(narrow-bridge) Vehicle:   18, prio: emer, direct: l -> r, ticks=  75
(narrow-bridge) Vehicle:   19, prio: emer, direct: l -> r, ticks=  86
(narrow-bridge) Vehicle:   12, prio: emer, direct: l -> r, ticks=  86
(narrow-bridge) Vehicle:    1, prio: norm, direct: l <- r, ticks=  97
(narrow-bridge) Vehicle:    2, prio: norm, direct: l <- r, ticks=  97
(narrow-bridge) Vehicle:    3, prio: norm, direct: l <- r, ticks= 108
(narrow-bridge) Vehicle:    4, prio: norm, direct: l <- r, ticks= 108
(narrow-bridge) Vehicle:    5, prio: norm, direct: l <- r, ticks= 120
(narrow-bridge) Vehicle:    6, prio: norm, direct: l <- r, ticks= 121
(narrow-bridge) Vehicle:    7, prio: norm, direct: l <- r, ticks= 131
(narrow-bridge) Vehicle:    8, prio: norm, direct: l <- r, ticks= 131
(narrow-bridge) Vehicle:    9, prio: norm, direct: l <- r, ticks= 141
(narrow-bridge) Vehicle:   10, prio: norm, direct: l <- r, ticks= 141
(narrow-bridge) end
Execution of 'narrow-bridge 0 10 10 0' complete.
```

4. ВЫВОД

В ходе лабораторной работы был изучен примитив синхронизации семафор и решена задача “узкого моста” в ОС Pintos. При продумывании алгоритма возникали некоторые сложности. Так, например, при использовании функции thread_yield в одном из разработанных решений возникали проблемы с переключением потоков и определением, какая же машина поедет первой. Скорее всего, это связано со слишком большой “цепочкой” вызовов и гонкой процессов или с тем, что при вызове этой функции отключаются системные прерывания. Так же проблематично было решить проблему последней машины скорой помощи, то есть без использования отдельной конструкции else if. Хочется отметить, что использование thread_yield, теоретически, позволяло бы сократить количество использованных семафоров с 5 до 3. Так же в прошлых попытках решения был использован замок для сохранения целостности изменяемых процессом данных. Расположение функции захвата замка сильно влияла на отправку процессов на мост (в большинстве случаев машины могли ехать по одной).

ПРИЛОЖЕНИЕ

```
struct semaphore directions_sema[2][2];                 // Matrix with all semaphores
struct semaphore bridge_sema;                           // Semaphore of bridge
uint16_t cars_counts[2][2];                             // Number of all types of cars
uint16_t occupied_places = 0;                           // Occupied places on bridge
uint16_t current_cars_count, all_active_cars; // Number of current all cars and non blocked cars
uint16_t current_dir;                                   // Current bridge direction
uint16_t type;                                          // Type of car
bool is_moving_started;

void narrow_bridge_init(void)
{
    is_moving_started = false;
    type = 0;
    sema_init(&bridge_sema, 1);
    for (int i = 0; i < 2; i++)
    {
        sema_init(&directions_sema[i][0], 0);
        sema_init(&directions_sema[i][1], 0);
    }
}

/*
Set two cars of one type if bridge if full emty
*/
void _up_two_to_bridge()
{
    for (uint8_t i = 0; i < 2; i++)
    {
        sema_up(&directions_sema[type][current_dir]);
        sema_down(&bridge_sema);
    }
    occupied_places += 2;
    type = 0;
}
```

```
void _up_solo_to_bridge()
{
    sema_down(&bridge_sema);
    sema_up(&directions_sema[type][current_dir]);
    sema_down(&bridge_sema);
    occupied_places++;
    type = 0;
}

/*
Move normal car with emergency if emergency is last on current direction
*/
void _last_emer_w_normal()
{
    sema_up(&directions_sema[1][current_dir]);
    sema_up(&directions_sema[0][current_dir]);
    sema_down(&bridge_sema);
    sema_down(&bridge_sema);
    occupied_places += 2;
}

/*
Choose correct cars to move
*/
void move_to_bridge()
{
    if (cars_counts[1][current_dir] >= 2) // We have two blocked emergency
    {
            type = 1;
            _up_two_to_bridge();
    }
    else if (cars_counts[1][current_dir] == 1) // Last emergency on current direction
    {
            if (cars_counts[0][current_dir] >= 1)
```

```
                {
                        _last_emer_w_normal();
                }
                else
                {
                        type = 1;
                        _up_solo_to_bridge();
                }
        }
        else if (cars_counts[0][current_dir] >= 2) // We have two normal blocked cars and empty bridge
        {
                _up_two_to_bridge();
        }
        else if (cars_counts[0][current_dir] == 1) // We have the last car on current direction
        {
                _up_solo_to_bridge();
        }
        else
        {
                for (uint8_t i = 0; i < 2; i++)
                {
                        sema_down(&bridge_sema);
                }
        }
    }

    void arrive_bridge(enum car_priority prio, enum car_direction dir)
    {
        cars_counts[prio][dir]++;
        thread_yield(); // Count all types of cars
        if (!is_moving_started)
        {
                current_dir = ((cars_counts[1][0] > cars_counts[1][1] && cars_counts[1][0] != cars_counts[1][1]) ? dir_left : dir_right); // Choose start direction
                if (cars_counts[1][0] == cars_counts[1][1])
                        current_dir = ((cars_counts[0][0] >= cars_counts[0][1]) ? dir_left : dir_right);
```

```
                all_active_cars = cars_counts[0][0] + cars_counts[0][1] + cars_counts[1][0] + cars_counts[1][1];
                is_moving_started = true;
        }
        if (all_active_cars > 1) // Block all cars and move them to their semaphores
        {
                all_active_cars--;
                sema_down(&directions_sema[prio][dir]);
        }

        if (all_active_cars == 1) // If last non blocked car then we should start "list"
        {
                all_active_cars--;
                for (uint8_t i = 0; i < 2; i++)
                {
                        sema_up(&bridge_sema);
                }
                move_to_bridge();
                sema_down(&directions_sema[prio][dir]);
        }
    }

    void exit_bridge(enum car_priority prio, enum car_direction dir)
    {
        cars_counts[prio][dir]--;
        current_cars_count = cars_counts[0][0] + cars_counts[0][1] + cars_counts[1][0] + cars_counts[1][1]; // Count all cars
        occupied_places--;
        if (current_cars_count && occupied_places % 2 == 0) // If we have cars and our bridge is not empty
        {
                if (!cars_counts[1][current_dir ^ 1] && cars_counts[1][current_dir])
                        current_dir ^= 1;
                if ((current_dir == dir_right || current_dir == dir_left) && !(cars_counts[0][current_dir ^ 1] + cars_counts[1][current_dir ^ 1]))
                        current_dir ^= 1;
                current_dir ^= 1;
```

```
            for (uint8_t i = 0; i < 2; i++) // Move cars from bridge
            {
                sema_up(&bridge_sema);
            }
            move_to_bridge();
        }
    }
```