神经网络算子调度与图模式匹配

7.1 图模式匹配

Graph Pattern Matching

一个计算图可以表示为一个由节点、边集、输入边、输出边组成的四元组 C = {N, E, I, O}。

我们往往需要在计算图中寻找**指定结构**

- 如何用一个严谨的方式定义**结构**？
- 如何设计模式匹配算法，使得其尽可能高效？

7.1 图模式匹配

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一个计算图可以表示为一个由节点、边集、输入边、输出边组成的四元组 C = {N, E, I, O}。

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- 如何用一个严谨的方式定义结构？
- 如何设计模式匹配算法，使得其尽可能高效？

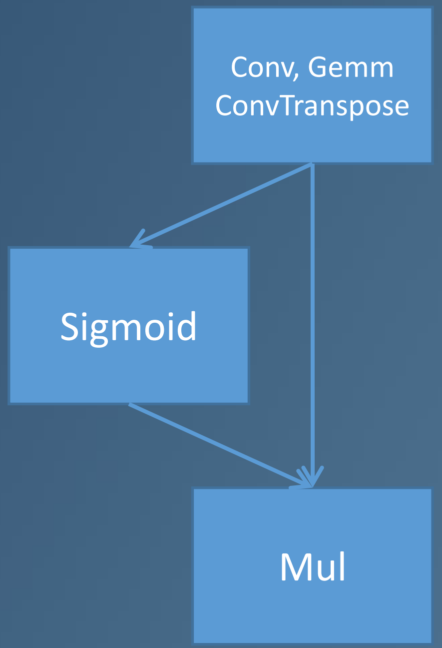
- 图模式匹配是量化算法、算子融合、算子调度的基础。

7.1 为什么需要图模式匹配

Why Graph Pattern Matching

例子1 ： Swish 算子图融合

```
search_engine = SearchableGraph(graph)
results = search_engine.pattern_matching(
            patterns = [lambda x: x.is_computing_op, 'Sigmoid', 'Mul'],
            edges = [[0, 1], [1, 2], [0, 2]],
            exclusive = True)
for computing_op, sigmoid, mul in results: ...
```

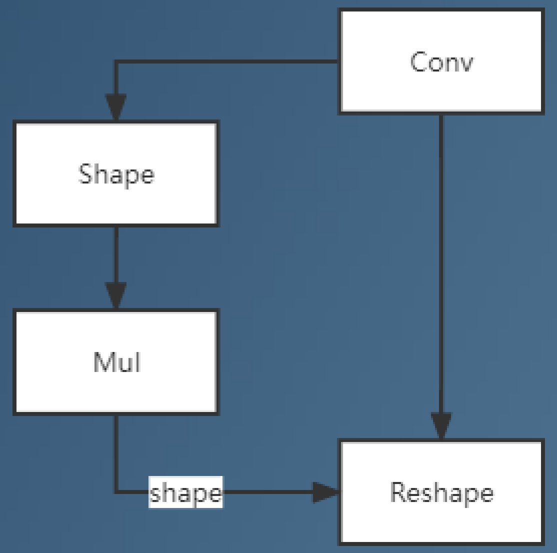


7.1 为什么需要图模式匹配

Why Graph Pattern Matching

例子2：算子调度

```
shape_backward_matching = search_engine.opset_matching(
        sp_expr = lambda x: x == shape,
        rp_expr = lamdba x, y: y.type not in {‘Reshape’, ‘Slice’, ...},
        ep_expr = lambda x: (x.type in {‘Reshape’, ‘Slice’, ...}),
        direction = 'down')
```



7.2 图模式匹配

Graph Pattern Matching

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            direction = 'down')
```

Traversal based matching

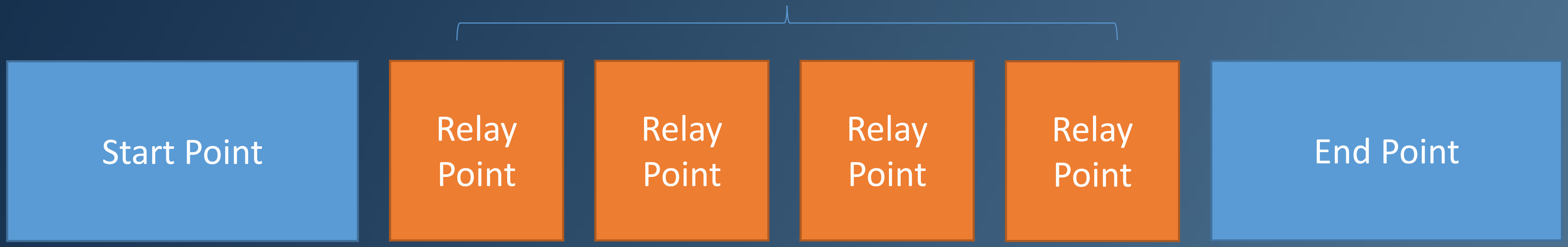
```
search_engine = SearchableGraph(graph)
results = search_engine.pattern_matching(
            patterns = [lambda x: x.is_computing_op, 'Sigmoid', 'Mul'],
            edges = [[0, 1], [1, 2], [0, 2]],
            exclusive = True)
for computing_op, sigmoid, mul in results: ...
```

Subgraph based matching

7.2.1 遍历模式匹配

Graph Traversal Pattern Matching

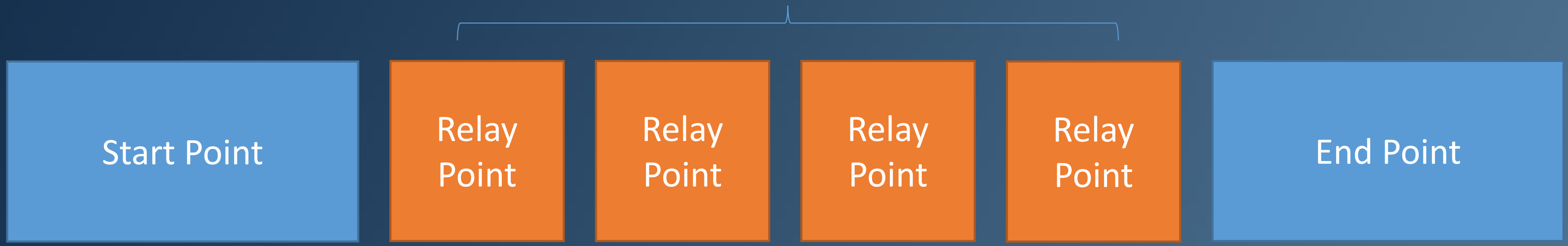
```
forward_matchings = search_engine(TraversalCommand(
    sp_expr=lambda x: ...,     (匹配起点表达式)      - - start point expression
    rp_expr=lambda x, y: ..., (匹配中继点表达式)   - - relay point expression
    ep_expr=lambda x: ...,     (匹配终点表达式)      - - end point expression
    direction='down'))
```



7.2.1 遍历模式匹配

Graph Traversal Pattern Matching

```
for operation in graph:
    if sp_expr(operation): # start point matched.
Iter:    next_op = next(operation)
         if ep_expr(next_op): return ret
         if rp_expr(next_op): goto Iter
```



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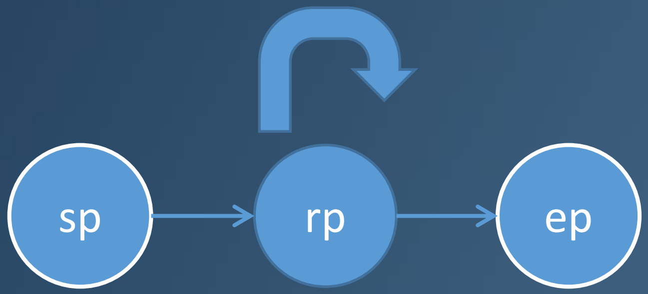
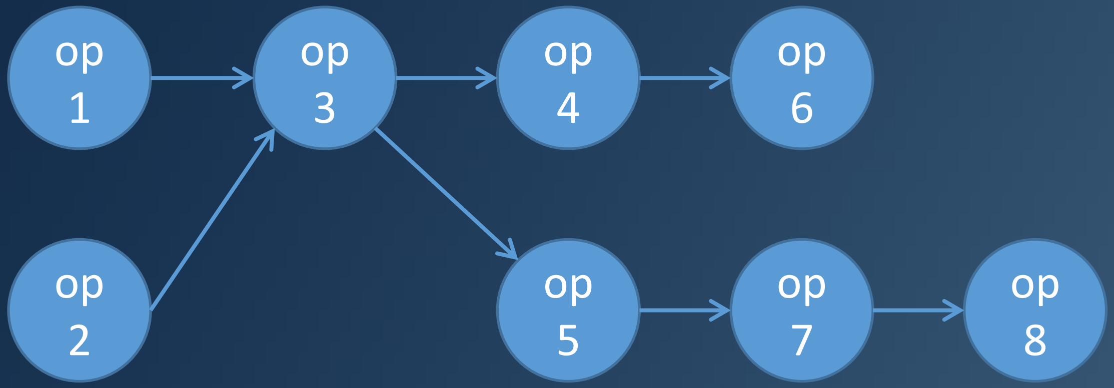


7.2.1 遍历模式匹配

Graph Traversal Pattern Matching

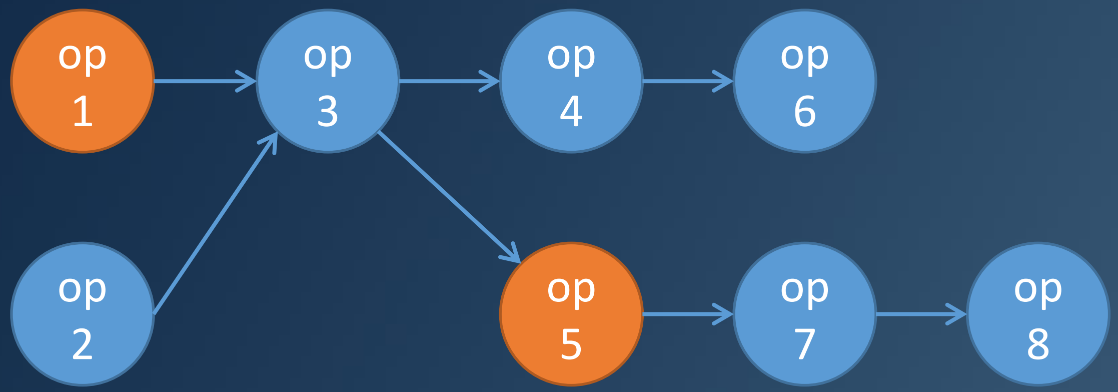


为了执行模式匹配，接下来我们需要将图逐步拆解成树，再到链。

1. 首先我们找出所有满足sp_expr的节点，将图拆解成一系列树
2. 再由树的根节点出发，将树剖分成链
3. 最后在链上执行模式匹配，期间可以利用动态规划进行优化

7.2.1 遍历模式匹配

Graph Traversal Pattern Matching



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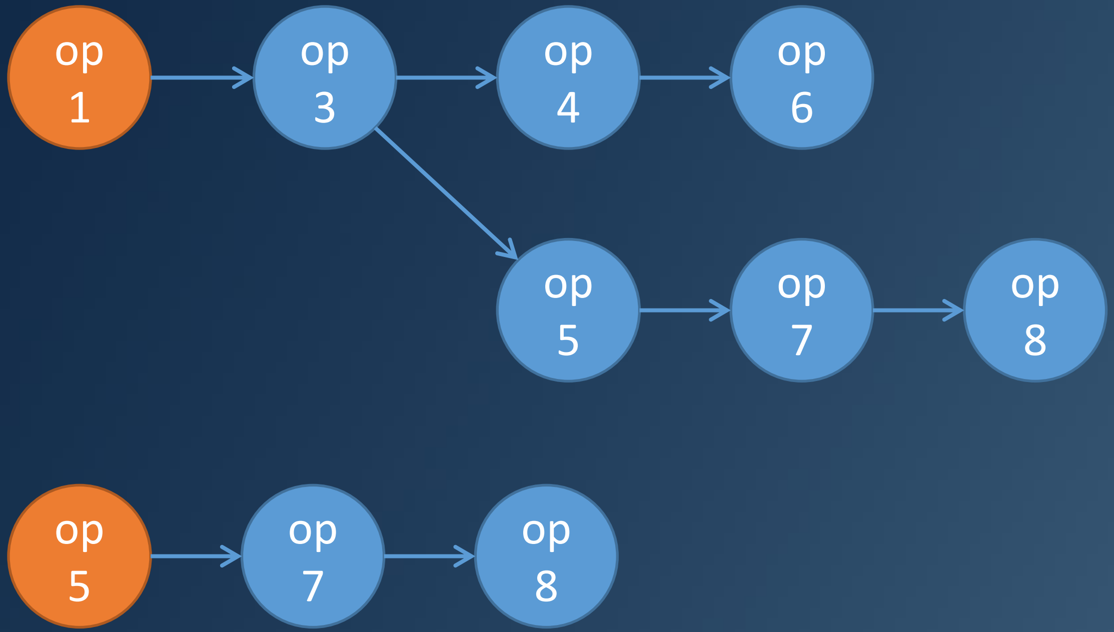

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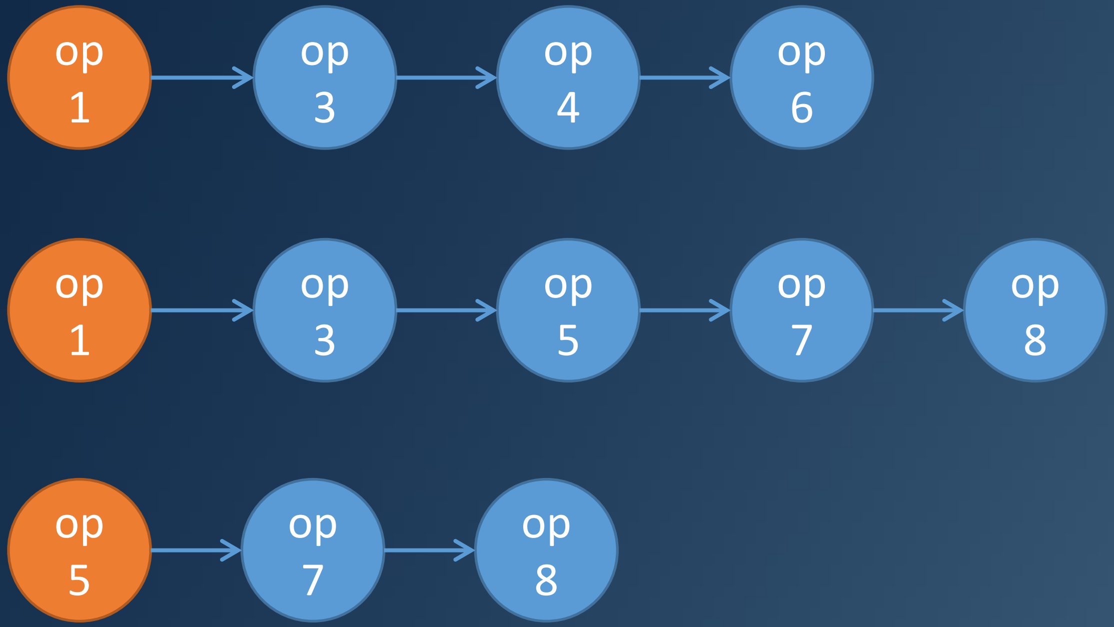
7.2.1 遍历模式匹配

Graph Traversal Pattern Matching



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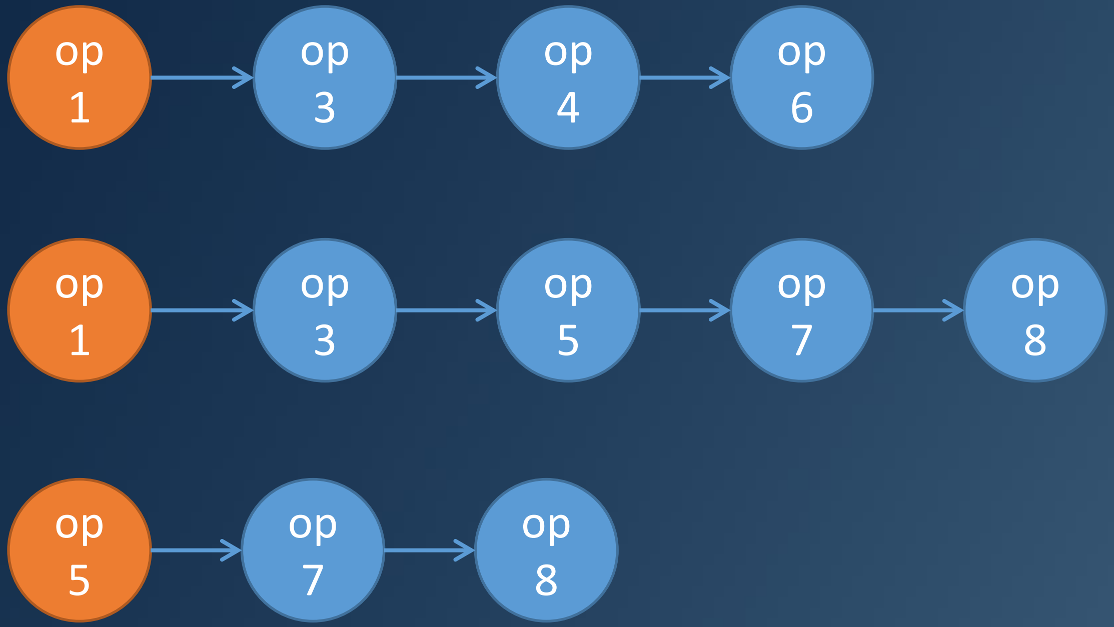

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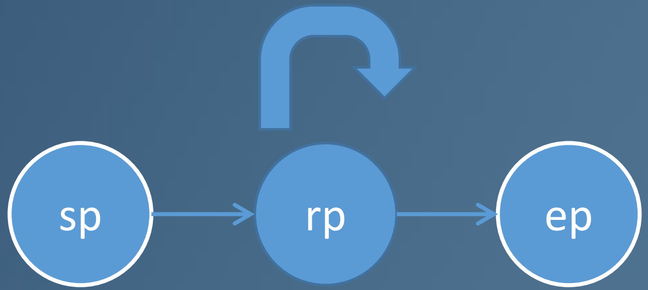
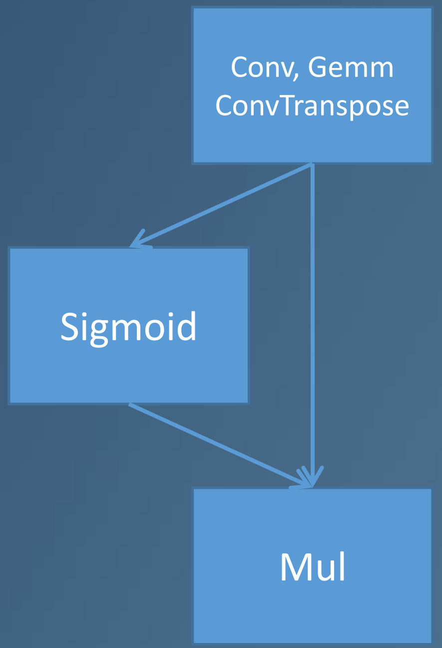


7.2.2 子图模式匹配

SubGraph Pattern Matching

```
search_engine = SearchableGraph(graph)
results = search_engine.pattern_matching(
            patterns = [lambda x: x.is_computing_op, 'Sigmoid', 'Mul'],
            edges = [[0, 1], [1, 2], [0, 2]],
            exclusive = True)
for computing_op, sigmoid, mul in results: ...
```



很遗憾，子图同构问题是NP-hard的

PPQ提供多项式复杂度的近似算法

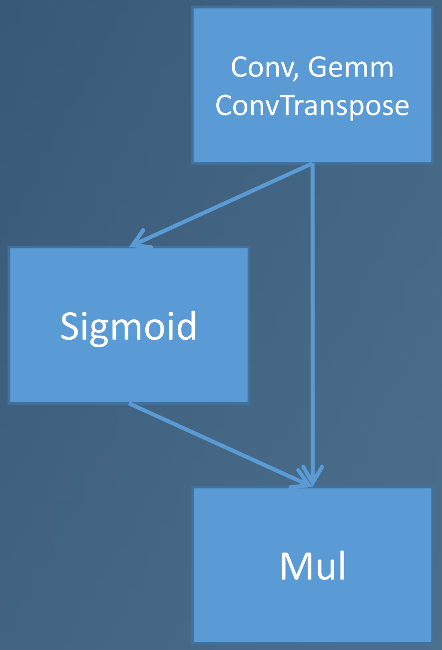
7.2.2 子图模式匹配

SubGraph Pattern Matching

```
for operation in graph:
    if operation.following == { 'Sigmoid', 'Mul' }
```

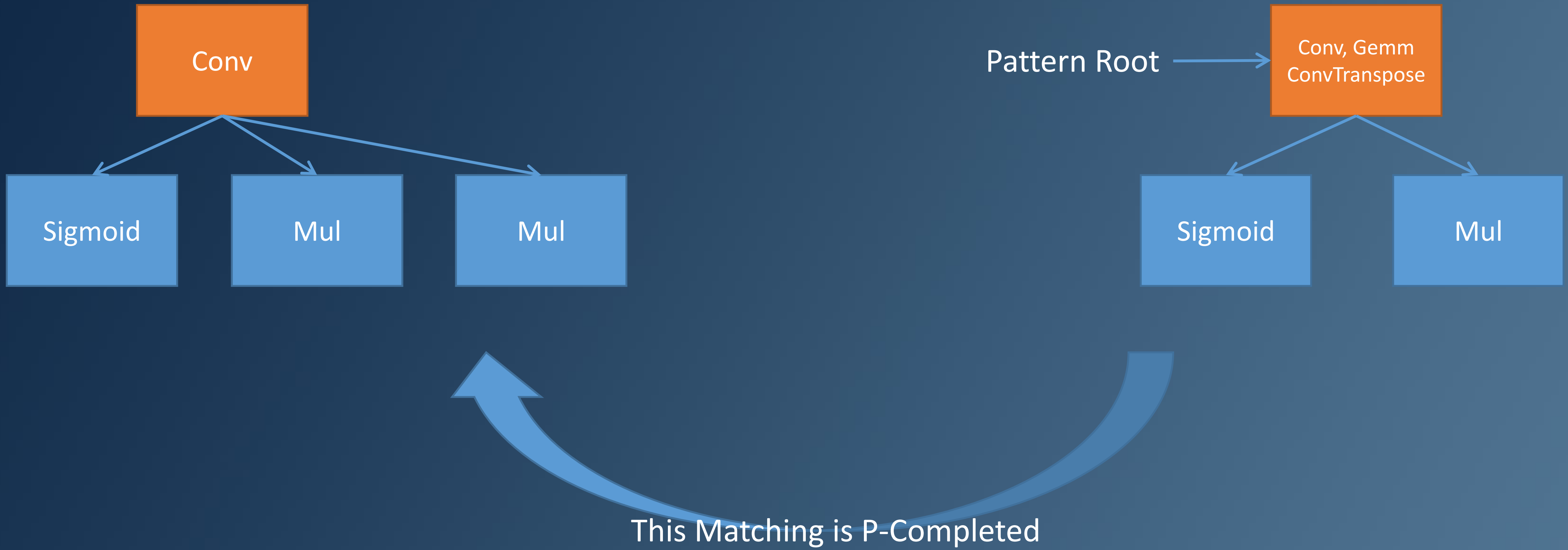
很遗憾，子图同构问题是NP-Hard的

PPQ提供多项式复杂度的近似算法



7.2.2 子图模式匹配

SubGraph Pattern Matching



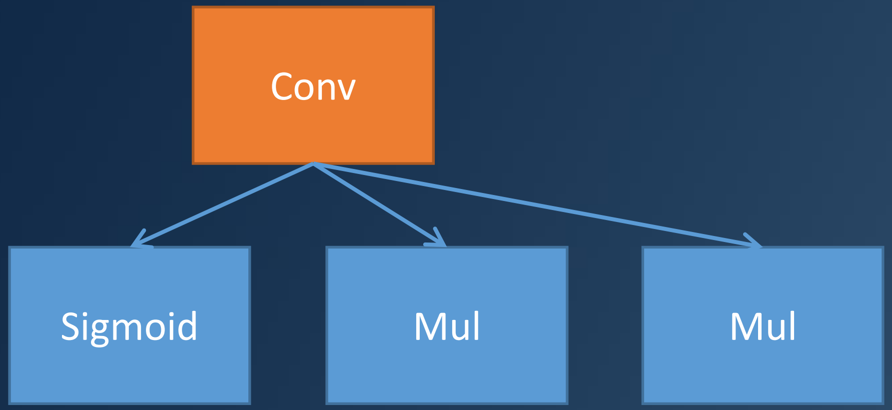
7.2.2 子图模式匹配

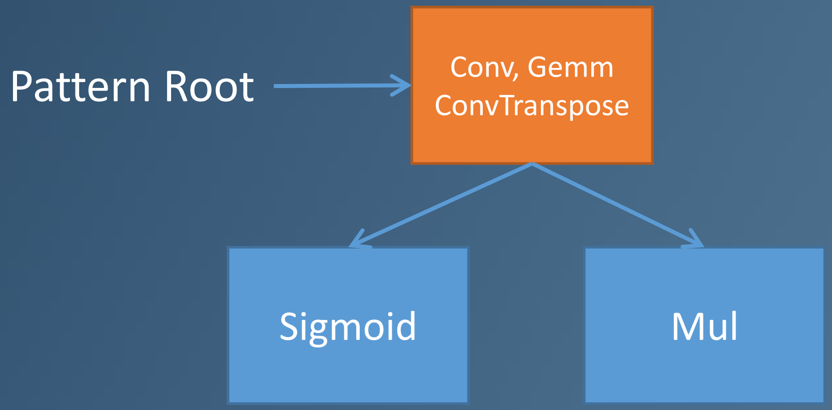
SubGraph Pattern Matching

For this situation, PPQ use Hungarian method to find an optimal matching(random).

7.2.2 子图模式匹配

SubGraph Pattern Matching



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        edges = [[0, 1], [1, 2], [0, 2]],
        exclusive = True)
for computing_op, sigmoid, mul in results: ...
```

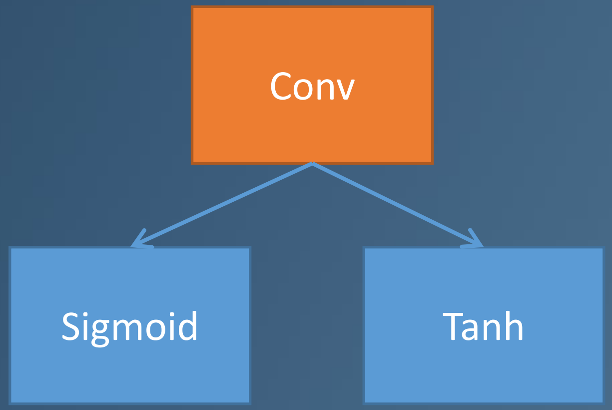
左图出现了失配节点，因此匹配直接失败。

7.2.2 子图模式匹配

SubGraph Pattern Matching

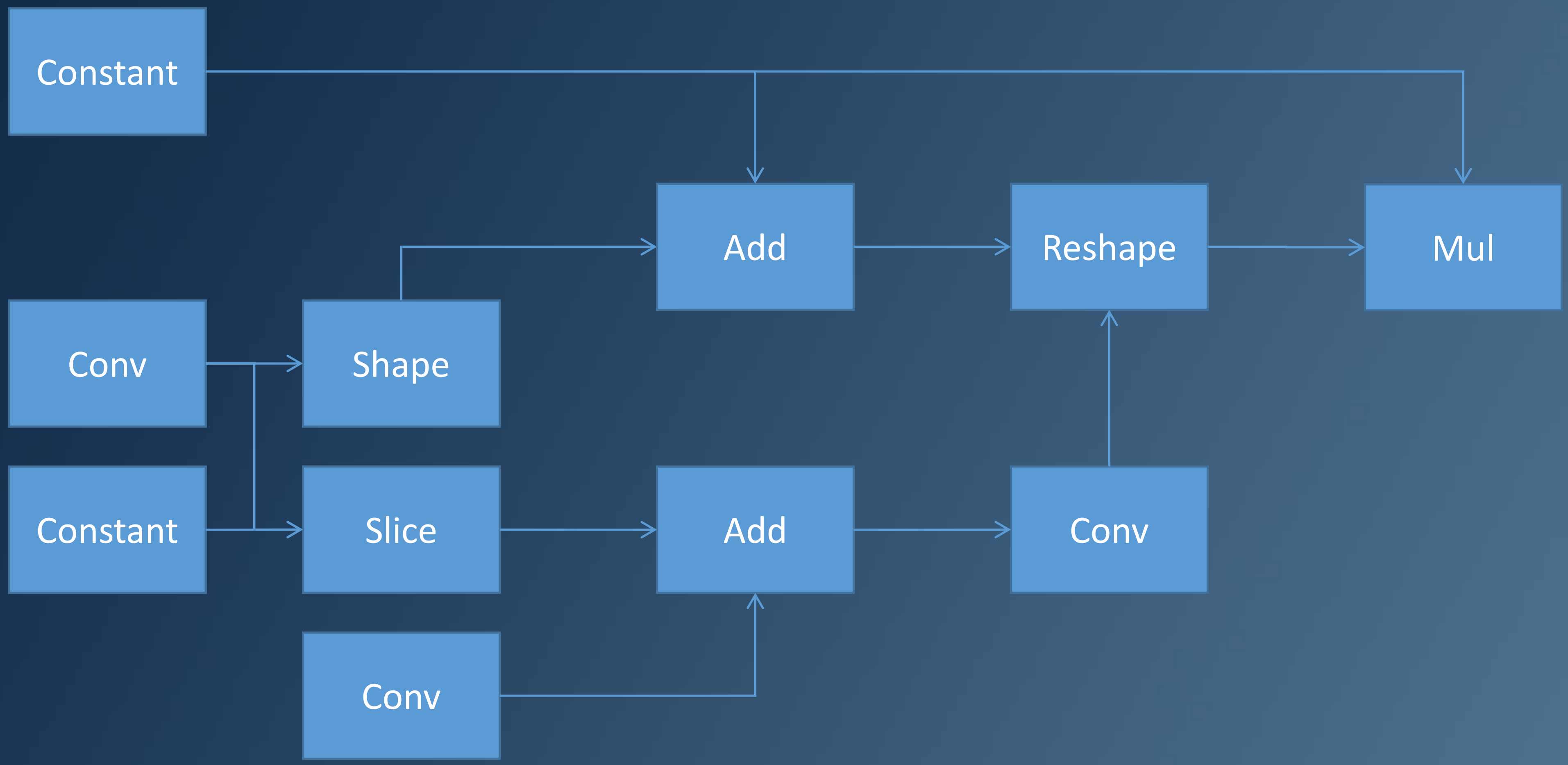
```
search_engine = SearchableGraph(graph)
results = search_engine.pattern_matching(
        patterns = [lambda x: x.is_computing_op, lambda x: x.type != 'Mul', lambda x: x.type != 'Mul'],
        edges = [[0, 1], [1, 2], [0, 2]],
        exclusive = True)
for computing_op, sigmoid, mul in results: ...
```

Do not use ambiguous pattern, it will cause random matching result, ppq will give warning about it.



7.3 算子调度

Graph Dispatching



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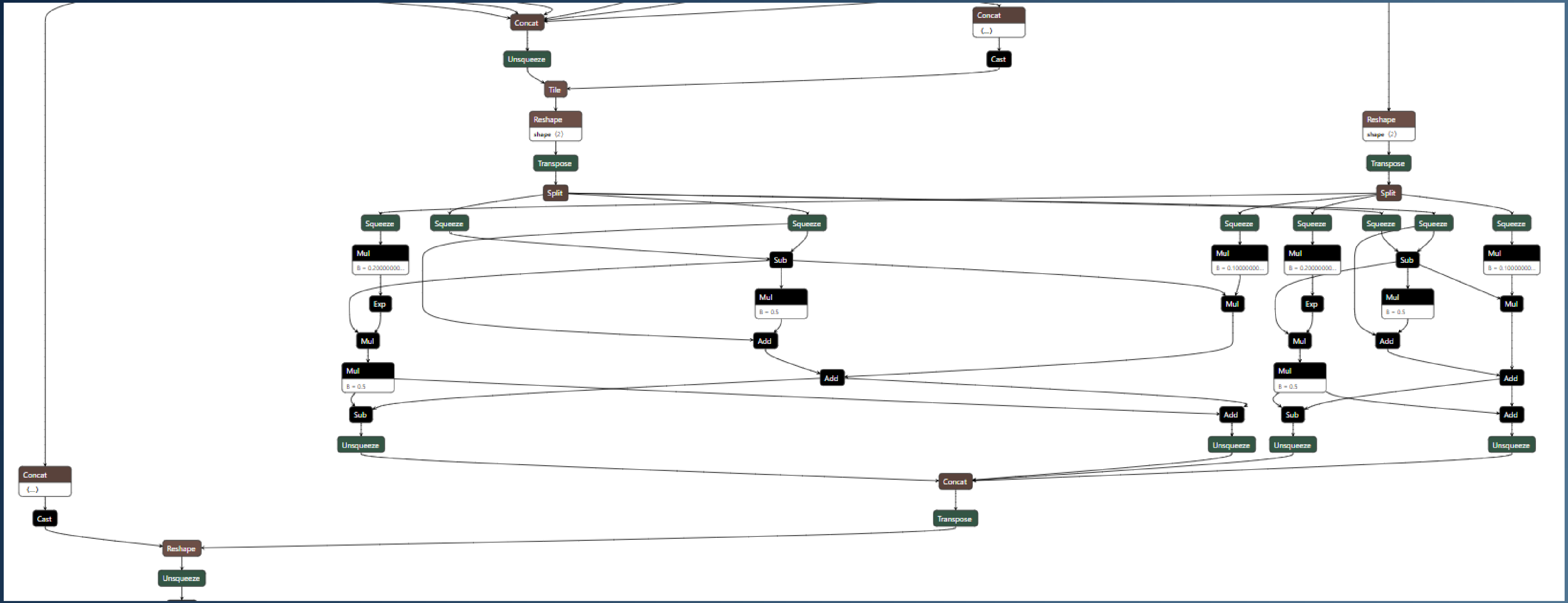
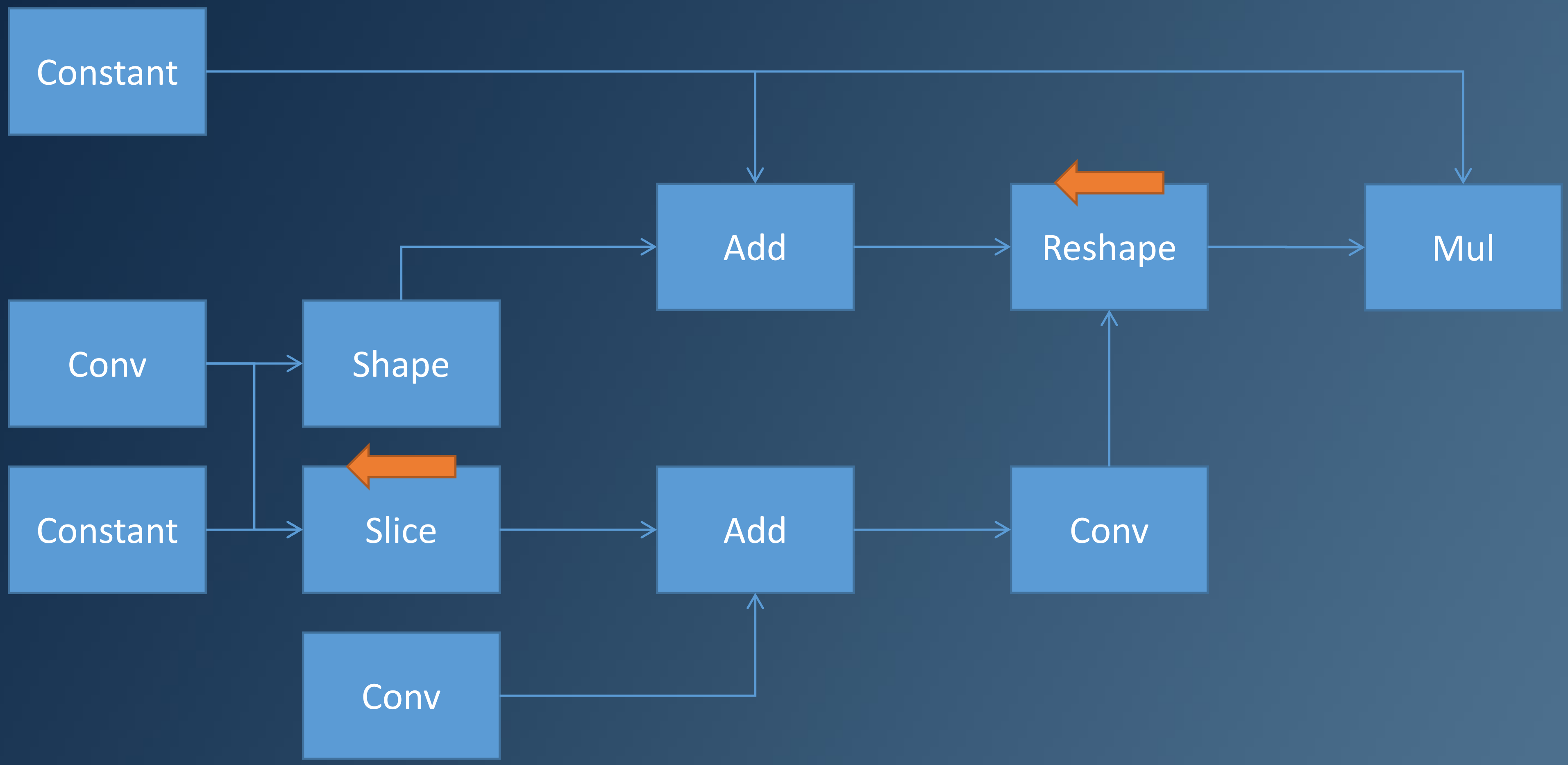


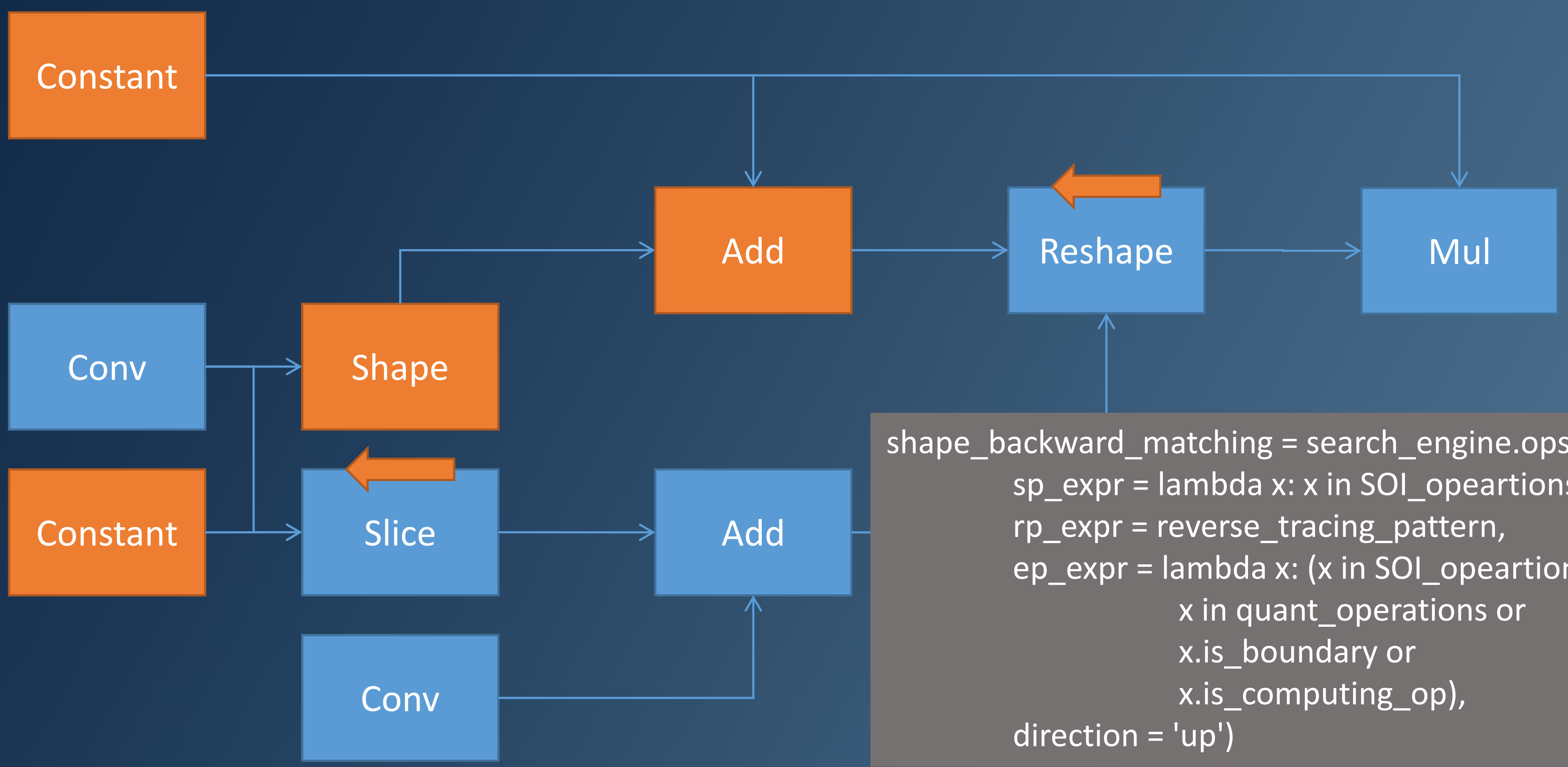
7.3 算子调度

Graph Dispatching



7.3.1 SOI 反向传播

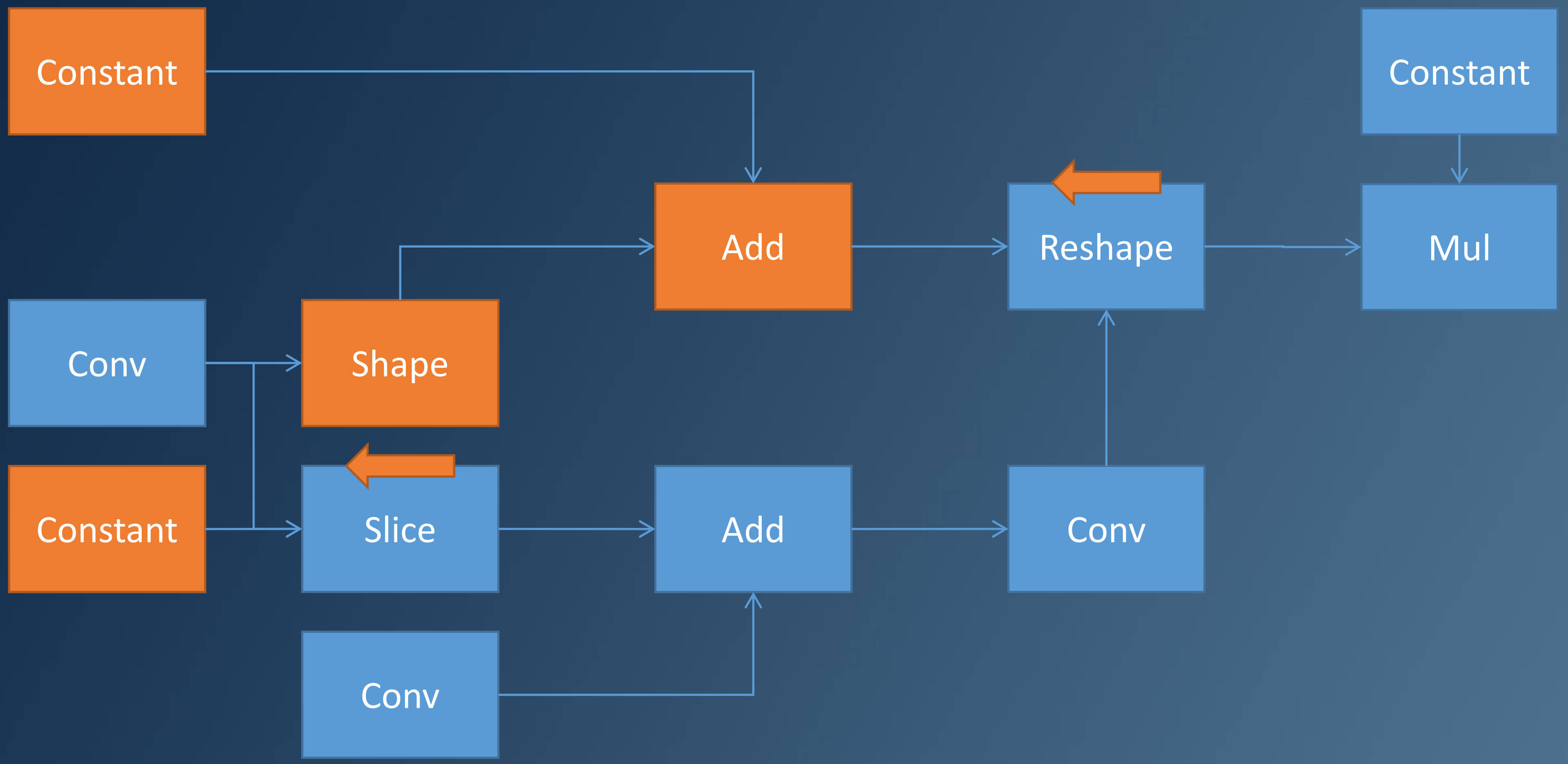
SOI backwards




```
shape_backward_matching = search_engine.opset_matching(
        sp_expr = lambda x: x in SOI_opeartions,
        rp_expr = reverse_tracing_pattern,
        ep_expr = lambda x: (x in SOI_opeartions or
                    x in quant_operations or
                    x.is_boundary or
                    x.is_computing_op),
        direction = 'up')
```

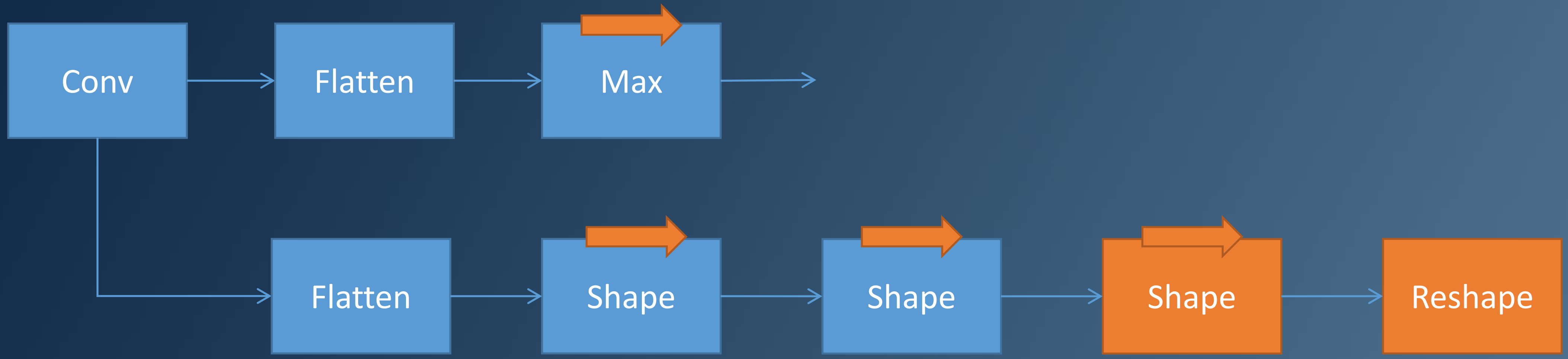
7.3.2 常量分裂

Constant Split



7.3.3 SOI 正向传播

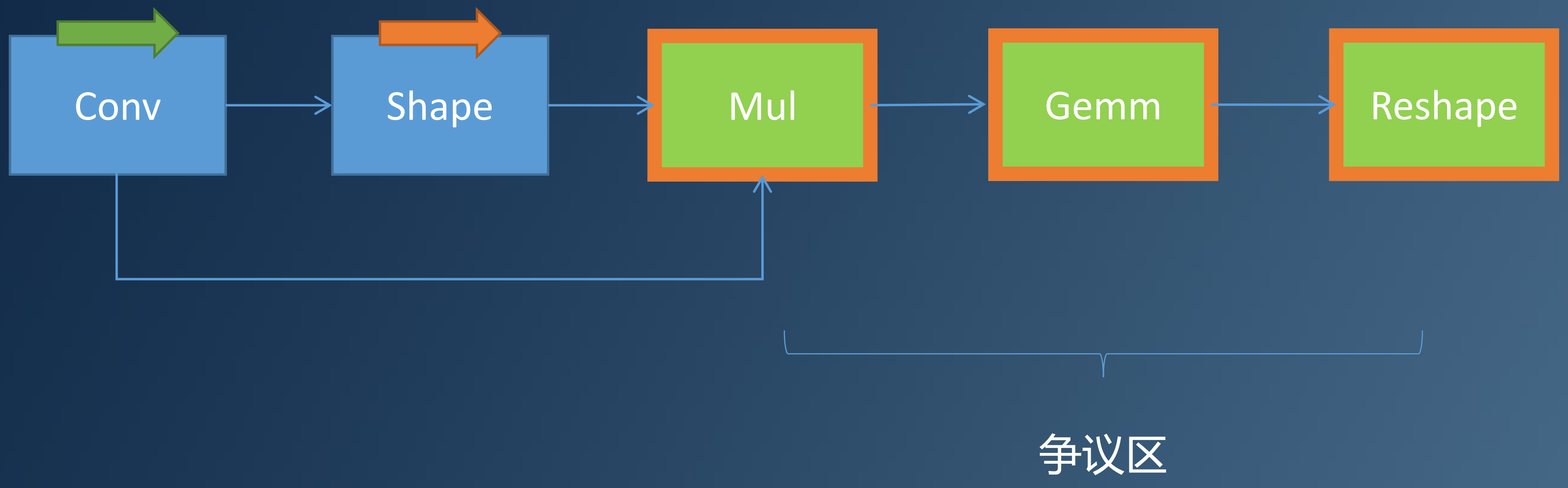
SOI forwards




```
shape_forward_matching = search_engine.opset_matching(
    sp_expr = lambda x: x in generators and x.type not in {'Constant'},
    rp_expr = value_tracing_pattern,
    ep_expr = lambda x: x in recivers or x in quant_operations or x.is_boundary,
    direction = 'down')
```

7.3.5 调度争议区

Dispatching Conflict Area

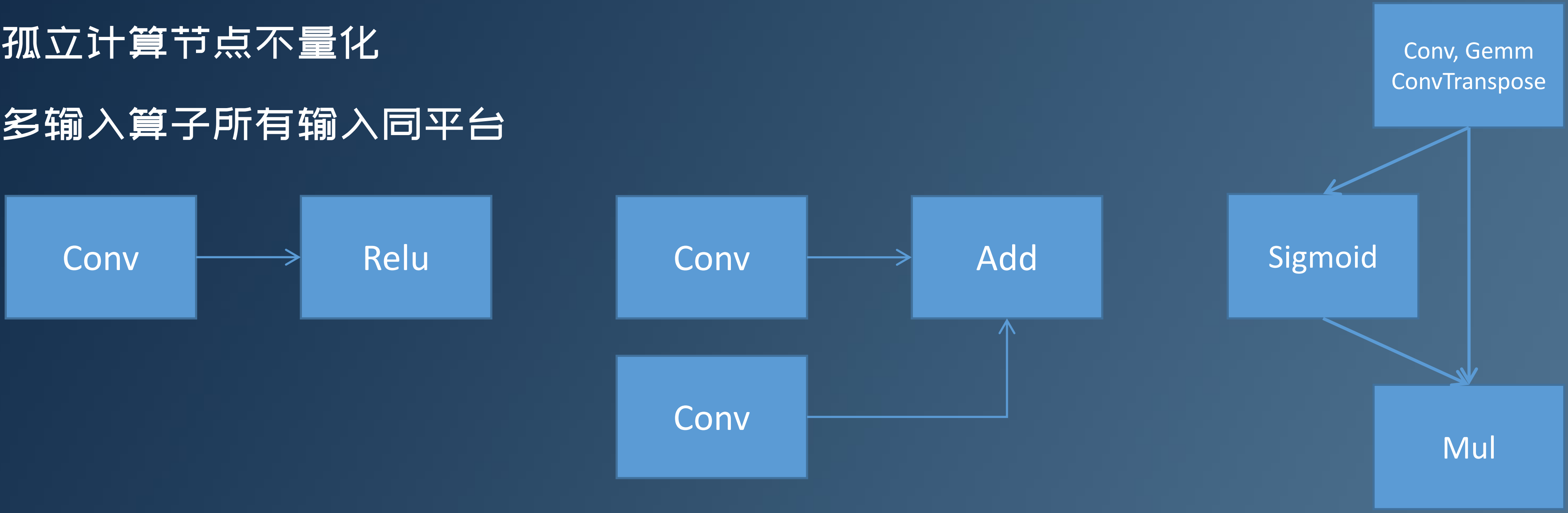


- AggresiveDispatcher: 所有争议区算子视为可量化算子
- ConservativeDispatcher: 所有争议区算子视作不可量化算子

7.3.6 调度约束

Dispatching Principles

- 激活函数与计算节点保持统一平台
- NMS，SHAPE，TOPK，MAX与计算节点保持同一平台
- 参与图融合的算子保持统一平台
- 孤立计算节点不量化
- 多输入算子所有输入同平台



7.3.6 调度约束

Dispatching Principles

- 激活函数与计算节点保持统一平台
- NMS, SHAPE, TOPK, MAX与计算节点保持同一平台
- 参与图融合的算子保持统一平台
- 孤立计算节点不量化
- 多输入算子所有输入同平台

7.3.7 手动调度

PPQ dispatching table

```
quant_setting = QuantizationSettingFactory.default_setting()
quant_setting.equalization = True # use layerwise equalization algorithm.
quant_setting.dispatcher   = 'conservative' # dispatch this network in conservertive way.

reports = layerwise_error_analyse(
    graph=quantized, running_device=DEVICE, collate_fn=collate_fn,
    dataloader=calibration_dataloader)
```

```
Conv_4:   | ████████████████████ |
0.015058
Conv_138: | █████                | 0.003621
Conv_32:  | ████                 | 0.002722
Conv_133: | ███                  | 0.002622
Conv_22:  | ███                  | 0.001980
Conv_142: | ███                  | 0.001965
Conv_109: | ██                   | 0.001746
Conv_123: | ██                   | 0.001680
Conv_119: | ██                   | 0.001645
Conv_100: | ██                   | 0.001411
Conv_13:  | ██                   | 0.001378
```

7.3.7 手动调度

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quant_setting.dispatching_table.append( 'Conv4', TargetPlatform.FP32)
quant_setting.dispatching_table.append( 'Conv138', TargetPlatform.FP32)
```

7.3.7 手动调度

PPQ dispatching table

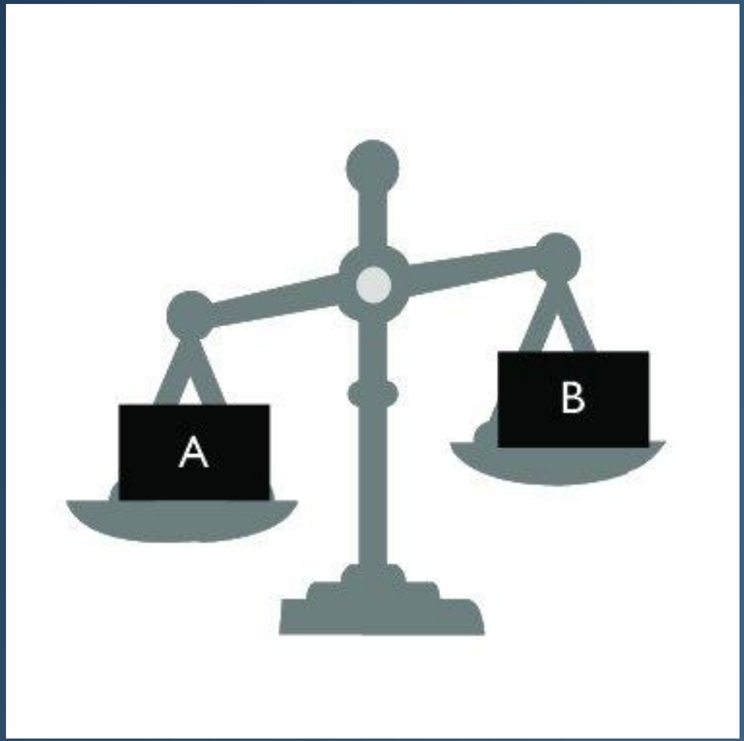
你需要知道手动调度对于量化而言意味着什么：

- 对于CPU, GPU而言，被调度到FP32平台的算子将牺牲计算时间来换取计算精度，在量化子图与非量化子图之间将存在精度转换节点。在这样的硬件上，网络的量化其实只是在权衡网络精度与速度。
- 对于FPGA, DSP而言，硬件端没有浮点运算能力，手动调度算子可能造成网络无法执行。在最优情况下，浮点算子将被调度到主机端进行运算，为此你的推理框架需要对此有相应实现，并且有设备流水线的功能。
- 混合精度量化调度极度复杂，如果你对 1-8 bit 混合精度量化感兴趣，请注意真实的计算绝不是简单地将conv, gemm等调度到到不同平台，而是牵连着许多算子一同调度，其过程是难以工业化的。

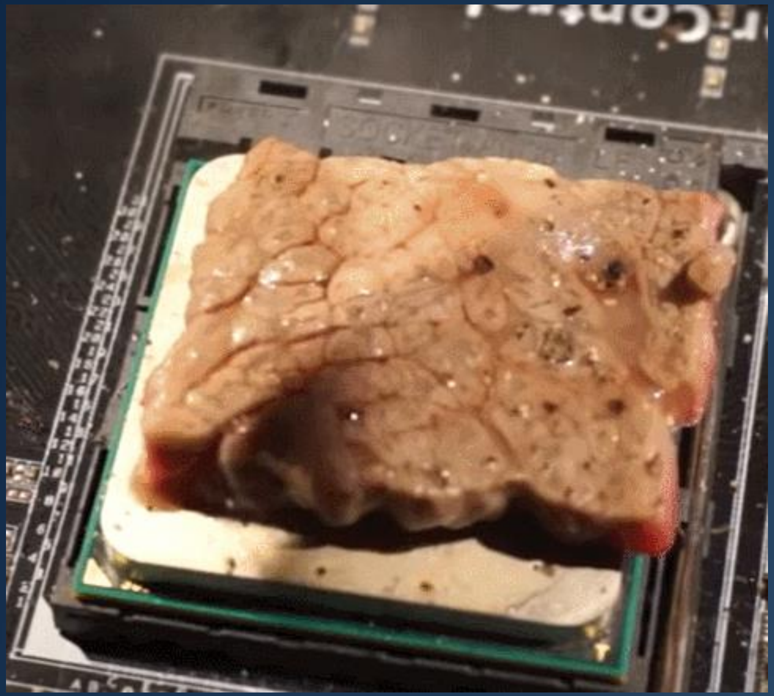
7.3.7 手动调度

PPQ dispatching table

- 在真正的部署过程中，量化实际上是一个执行速度与网络精度权衡问题。
- 网络调度是量化走向工业化所必须的特性，是稳定部署所必须的。



联系我们 https://github.com/openppl-public



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