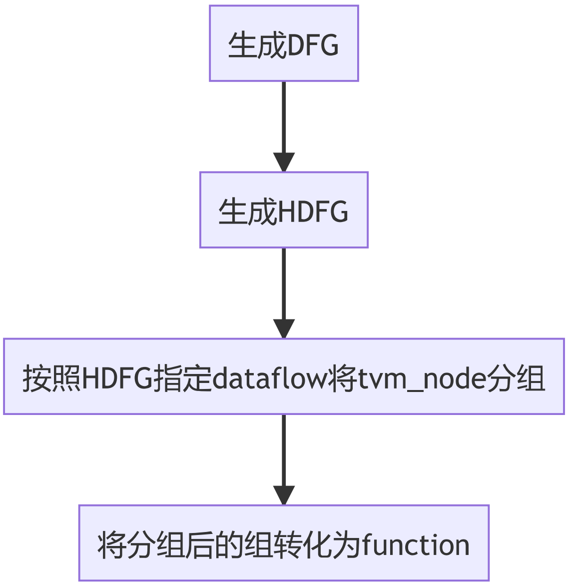
fuse_op_hw Pass HW算子融合逻辑

1 总貌

tvm前端解析出来网络module并转化为Relay IR后，fuse_op_hw Pass做了以下几件事：



其中

class	class annotation
DFG	data flow graph，用来作为tvm node和HDFG node之间的过渡，是tvm node的映射
Creator	DFG用来完成node映射的helper class
HDFG	Hardware data flow graph，将tvm IR转化为指定OPU的IR，并进行对node的分组
GraphMatchFuser	用来完成node fusion并将group转化为function的helper class

function	function annotation
DFG::Creator::Prepare	完成tvm node到DFG node的映射，分三步：建立映射表、遍历每个node并根据类型映射、更新node父子关系
DFG::Creator::VisitExpr_	自定义重载func，通过自定义AddNode来完成对tvm node的遍历和DFG node的映射
HDFG::Create	定义指定的data flow（该data flow便是一个组，例如cc中的data flow只允许存在一个pad，第二个pad将被归为第二组）
GraphMatchFuser::Partition	算子融合func，采用dfs贪心尽可能多的将node归为一个group
HDFG::FindMatch	广度遍历后序树，input为DFG node，return为bool_match，side effect为修改last_match值以完成一趟hardware data flow
GraphMatchFuser::CollectInputs	向上递归，将没有算进来的结点归为该group（例如constant等节点为新分支节点，没办法向下遍历时访问到，只能通过向上遍历）

2 Partition function细节分析

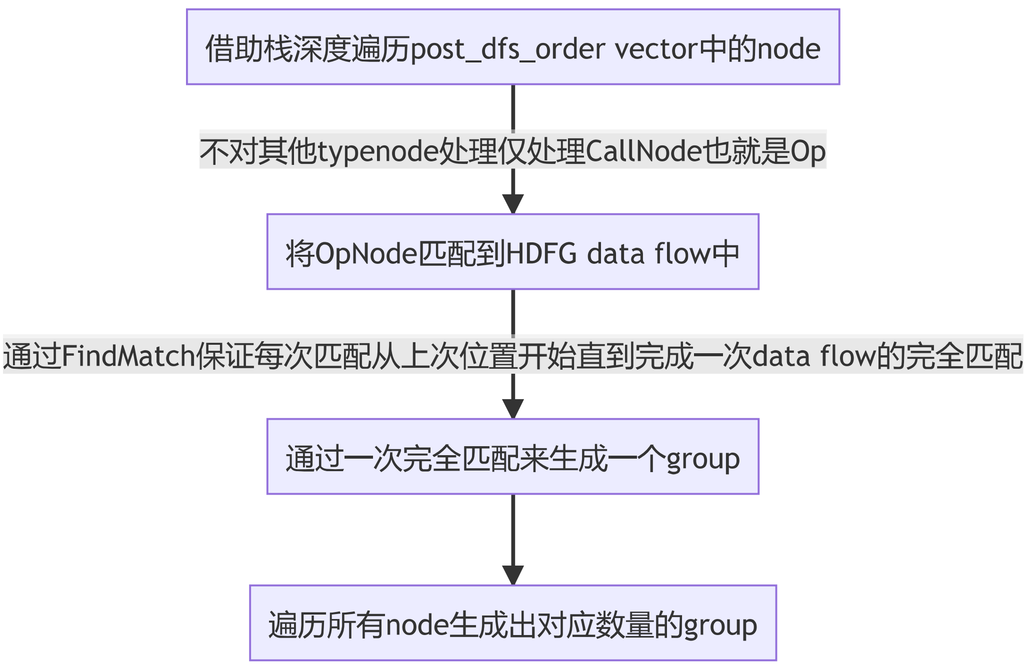
tvm的fuse_op使用了支配树来定义group division rule，而OPU通过定义hardware data flow来确定分组的规则，hardware data flow在Create func中定义：

```
// describe data flow
hdfg.root = concat;
hdfg.LinkFromTo(concat, add_pre); // concat -> add_pre
```

```
    hdfg.LinkFromTo(add_pre, mul_pre);
    hdfg.LinkFromTo(mul_pre, pad);
    hdfg.LinkFromTo(pad, ipa);
    hdfg.LinkFromTo(ipa, mul);
    hdfg.LinkFromTo(mul, add);
    hdfg.LinkFromTo(add, compare);
    hdfg.LinkFromTo(add, pool_pad);
    hdfg.LinkFromTo(add, res_add);
    hdfg.LinkFromTo(pool_pad, pool);
    hdfg.LinkFromTo(compare, pool);
    hdfg.LinkFromTo(compare, res_add);
    hdfg.LinkFromTo(pool, compare);
    hdfg.LinkFromTo(pool, res_add);
    hdfg.LinkFromTo(res_add, compare);
    hdfg.LinkFromTo(res_add, pool);
    hdfg.LinkFromTo(compare, upsample);
    hdfg.LinkFromTo(pool, upsample);
    hdfg.LinkFromTo(res_add, upsample);
    ...
```

可以得知data flow中padding和IPA(即conv2d)仅出现一次，故每一group中仅有一个pad，这在该data_flow中是关键信号。

Partition function整体逻辑flow如下：



而对于除了CallNode之外的类似VarNode、ConstantNode，均在AddToGroup func中的CollectInputs func中完成，CollectInputs func完成这样的操作：

```
  void GraphMatchFuser::AddToGroup(DFG::Node* node, Group* grp) {
    gmap_[node->ref] = grp;
```

```
  // update group root with the latest operator node (post dfs order)
  grp->root_ref = node->ref;
  // add all ungrouped preds
  // aim to collect nodes that cannot be mapped via hdfg.op_map
  // e.g. tuple, const, expand_dims
  // counterexample: tuple has 2 relu inputs, which are not considered below,
  // since they should be captured in the Partition() flow
  // 这是一个向上看的过程，从Op node开始将他上面的node均判断一遍
  for (auto pred : node->pred) {
    CollectInputs(pred, grp);
  }
}

/*
 * 向上递归的过程，将上面没有算进来的结点归为该group，
 * 例如constant等节点为新分支节点，没办法向下遍历时访问到，只能通过向上遍历
 * recursively add inputs of DFG:Node to target group
 * terminate until
 *   1. a root DFG::Node from other group is met
 *   2. a grouped DFG::Node is met
 *   3. a ungrouped DFG::Node, which is a CallNode and will be grouped later
 */
void GraphMatchFuser::CollectInputs(DFG::Node* node, Group* grp) {
  auto it = root_map.find(node->ref);
  if (it != root_map.end()) {
    return;
  } else if (gmap_.find(node->ref) != gmap_.end()) {
    return;
  } else {
    if (node->ref->IsInstance<TupleNode>()) {
      os << "tuple\n";
    } else if (node->ref->IsInstance<ConstantNode>()) {
      os << "const\n";
    } else if (node->ref->IsInstance<CallNode>()) {
      const CallNode* call = static_cast<const CallNode*>(node->ref);
      os << call->op << "\n";
      if (call->op.get()->IsInstance<OpNode>()) {
        // Operators in op_map will be taken care of in Partition()
        const OpNode* op = static_cast<const OpNode*>(call->op.get());
        auto ie = hdfg.op_map.find(op->name);
        if (ie != hdfg.op_map.end()) {
          return;
        }
      }
    } else if (node->ref->IsInstance<VarNode>()) {
```

```
        os << "var\n";
      } else {
        os << "unknown\n";
      }
      gmap_[node->ref] = grp;
      os << "## " << node->index << ": added to group " << grp->index
         << " via CollectInputs() \n";
    }
    for (auto pred : node->pred) {
      CollectInputs(pred, grp);
    }
  }
```

每次访问到一个OpNode时，通过pred关系向上递归遍历其他类型node，将这些node归为这个OpNode所在group。Partition中便通过这样的方式完成group分组：

```
      //只对Op_node进行操作，遇到其他类型node直接跳过，
      //比如刚开始跳过node[0]直接到node[1]:Op(nn.pad)，
      //在CollectInputs中将node[0]collect进来。
      if (node->ref->IsInstance<CallNode>()) {
        const CallNode* call = static_cast<const CallNode*>(node->ref);
        std::string opname = call->op.as<OpNode>()->name;
        //从last_match开始是因为在HDFG中定义了一块data_flow，
        //这一块data_flow便定义了一组可能的group，
        //所以会有没有find(因为一趟已经结束了)但是是能够找到Op的情况，这时候说明要开新group了。
        bool find = hdfg.FindMatch(node);
        auto it = hdfg.op_map.find(opname);
        if (find) {
          // mapped to hardware successfully, add to current group
          grp = GetLatestGroup();
          AddToGroup(node, grp);
          os << "## " << node->index << ": " << call->op
             << " added to group " << grp->index << "\n";
        } else if (it != hdfg.op_map.end()) {
          // primitive operator nodes cannot be mapped to hardware data flow
          // try restart mapping (bfs matching) from source of hardware data flow
          hdfg.last_match = nullptr;
          find = hdfg.FindMatch(node);
          if (find) {
            // successfully mapped after from hardware source
            // add node to a new group
            grp = GetLatestGroup(true);
            AddToGroup(node, grp);
            os << "## " << node->index << ": " << call->op
               << " added to group " << grp->index << "\n";
```

```
    }
  }
  ...
```