



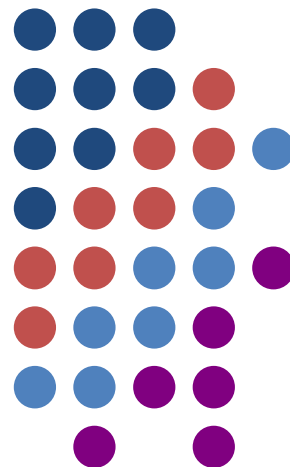
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

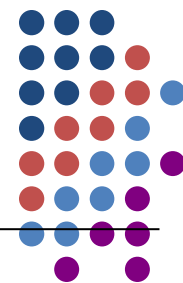
HEPS-BPIX4 DAQ基于机器学习目标检测 的在线图像数据压缩研究

肖鹏飞

触发与数据获取组

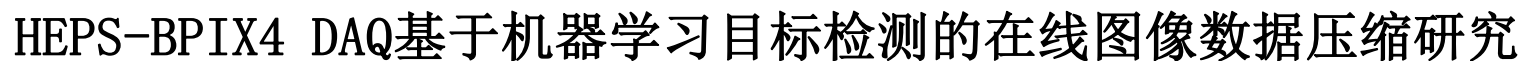
2024年10月17日



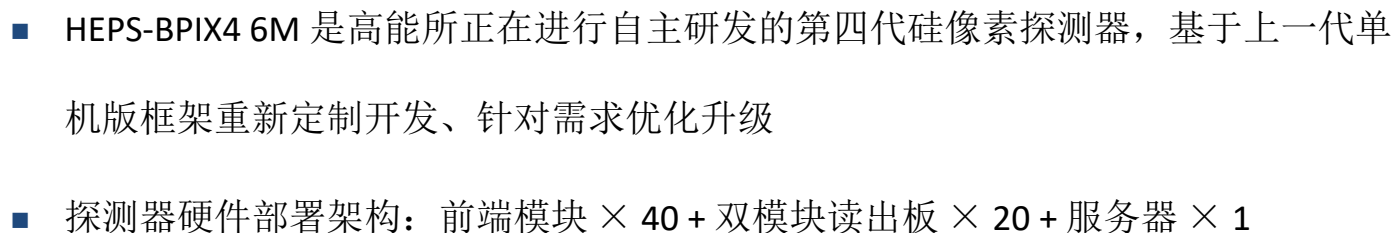
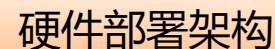


◆ HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究

- HEPS-BPIX4 DAQ
- HEPS-BPIX4 DAQ在线数据压缩
- YOLOv10实时端到端的目标检测模型
- 数据集准备与模型训练
- 训练模型的推理与图像压缩测试
- HEPS-BPIX4 DAQ框架部署测试



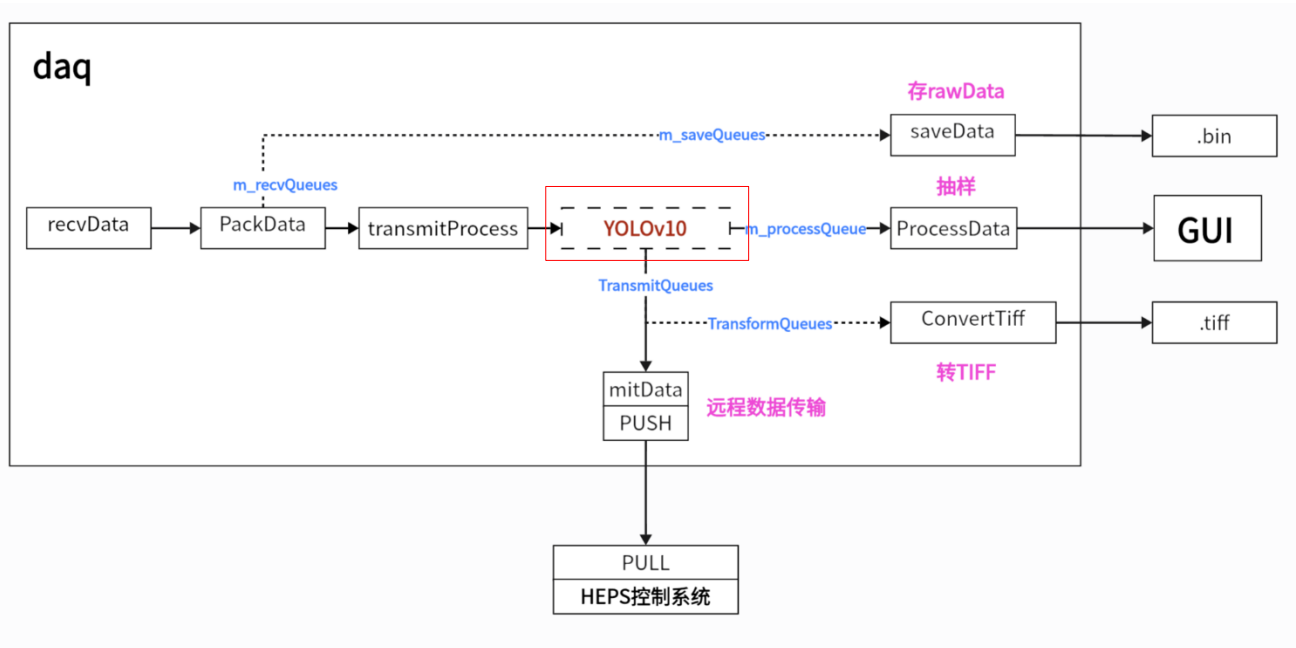
HEPS-BPIX4 6M DAQ框架设计





HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究

● HEPS-BPIX4 DAQ在线数据压缩



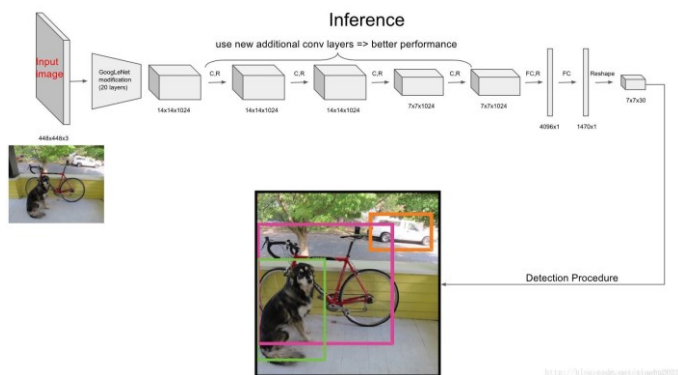
- 在原本的在线数据流框架中对图像数据进行目标区域的检测选取，以减小图像数据的大小实现图像数据的压缩，减轻后续数据处理和传输的压力
- 选用YOLOv10目标检测模型进行训练并于框架中进行部署和集成

HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究



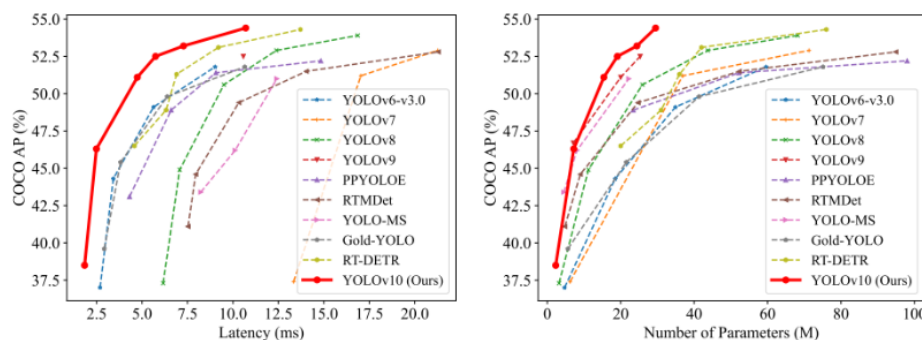
YOLOv10实时端到端的目标检测模型

YOLO 推理结构示意图



端到端的目标检测通过一次前向传播就可以完成检测图形目标的
位置和类别

YOLOv10 性能对比



与YOLOv9相比，在相同性能下，YOLOv10的延迟减少了46%，参数减少了25%

- YOLO实时目标检测算法的模型是一个轻量级的卷积神经网络，其目的是为了解决传统目标检测方法速度慢、效率低的问题
- YOLOv10模型于2024年5月23日发布，致力于打造实时端到端的高性能目标检测器，推理实时性相比于前代模型有较大的提升，贴合在线处理中对实时性的要求

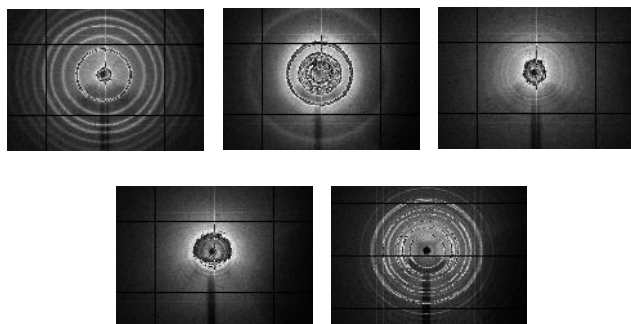
HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究



● 数据集准备与模型训练

YOLO数据集标注示意图

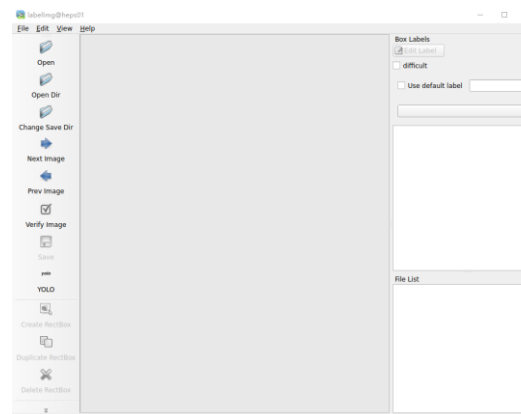
待标注数据集



导入



Labelling工具数据标注



数据集标注与分类（将不同类别的数据混合制作数据集，标注目标区域位置）

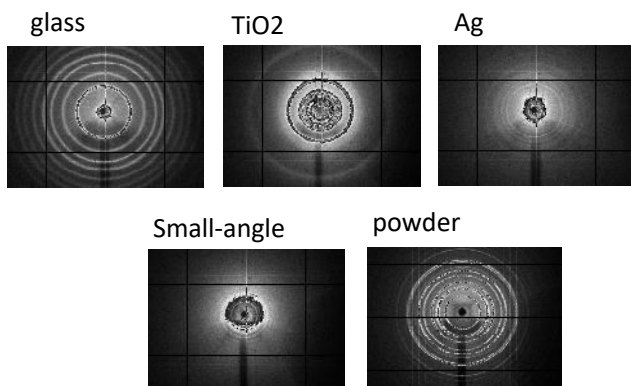
- 数据集标注的质量影响后续模型训练的效率和推理的准确性
- 标注过程主要为手工标注，自动标注工具需要提前导入已训练的模型（本研究未采用）

HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究



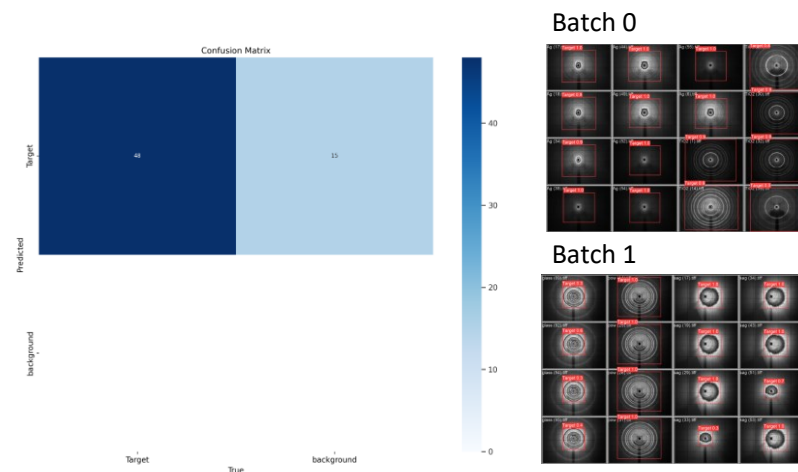
数据集准备与模型训练

数据集分类与标注



标注324张.tiff图片(TiO2/glass/Ag/small-angle/powder)生成324个标签数据集按Yolo格式进行划分(训练集: 226; 验证集: 48; 测试集: 50)

YOLO模型训练结果示意图



混淆矩阵

验证集测试

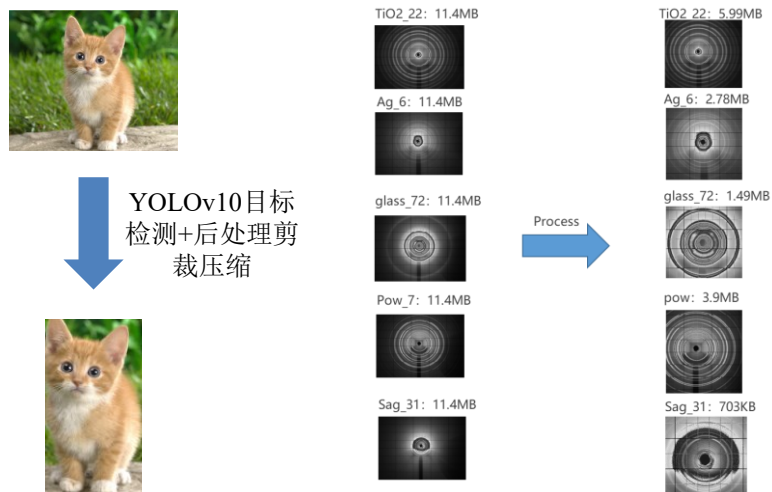
- 训练 A40单卡进行训练 (轮次: 100; 单批训练集大小: 16; 平均利用率: 83%)
- 验证集48个数据的验证结果 (识别48, 未识别0), 识别率100%

HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究



● 训练模型的推理与图像压缩测试

图像目标检测与压缩



推理性能测试

CPU部署测试

Latency/ms	Ag_6	Glass_72	Pow_7	Sag_31	TiO2_22
Preprocess	6.7	17.4	17.5	18.5	17.6
Inference	28	31.7	27.1	32.0	26.9
Postprocess	1.3	0.6	0.7	1.1	0.7
Utilization	251.3%	223.4%	241.3%	427.4%	407.9%

GPU部署测试

Latency/ms	Ag_6	Glass_72	Pow_7	Sag_31	TiO2_22
Preprocess	3.6	3.8	3.7	3.6	3.6
Inference	3.7	3.7	3.7	3.8	3.6
Postprocess	0.9	0.9	0.9	1.0	0.9
Utilization	79%	73%	100%	60%	65%

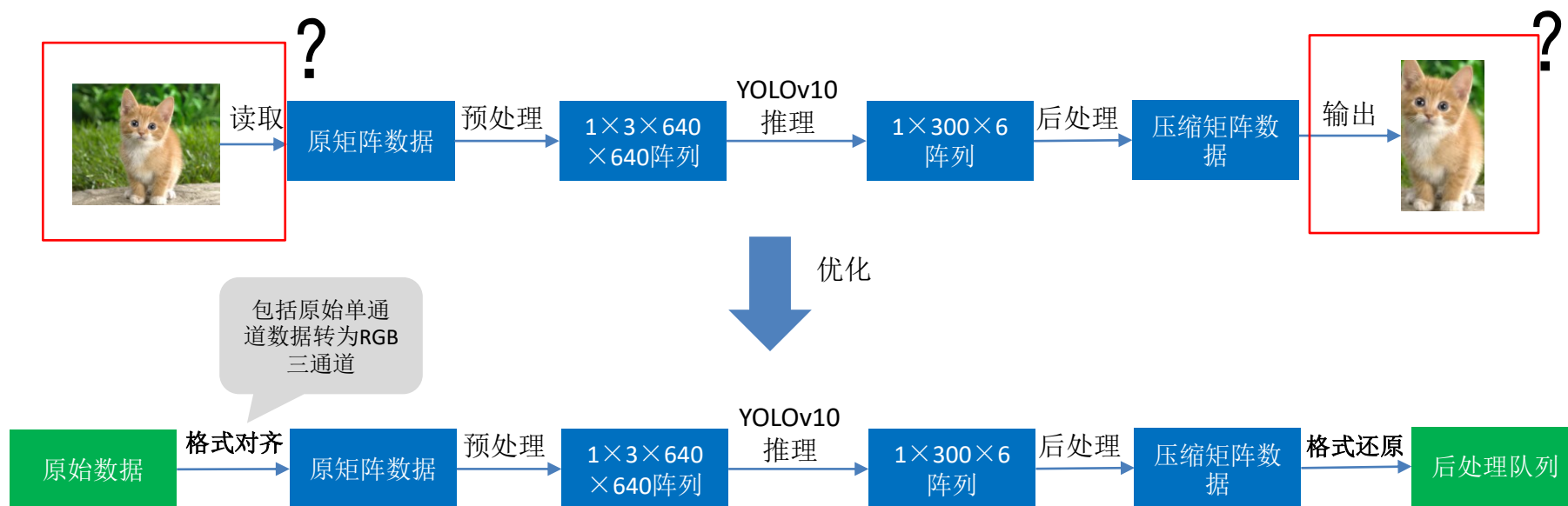
- 修改模型的图像后处理逻辑，实现输入图像的**剪裁压缩**
- Intel Xeon 8462Y+ CPU部署测试的单张图像的处理平均时延为**45.56ms**，平均利用率为**310.26%**；
Nvidia A40 GPU部署测试的单张图像的处理平均时延为**8.28ms**，平均利用率为**75.4%**。平均压缩**73.95%**

HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究



● HEPS-BPIX4 DAQ框架部署测试

HEPS-BPIX4 DAQ数据流部署设计



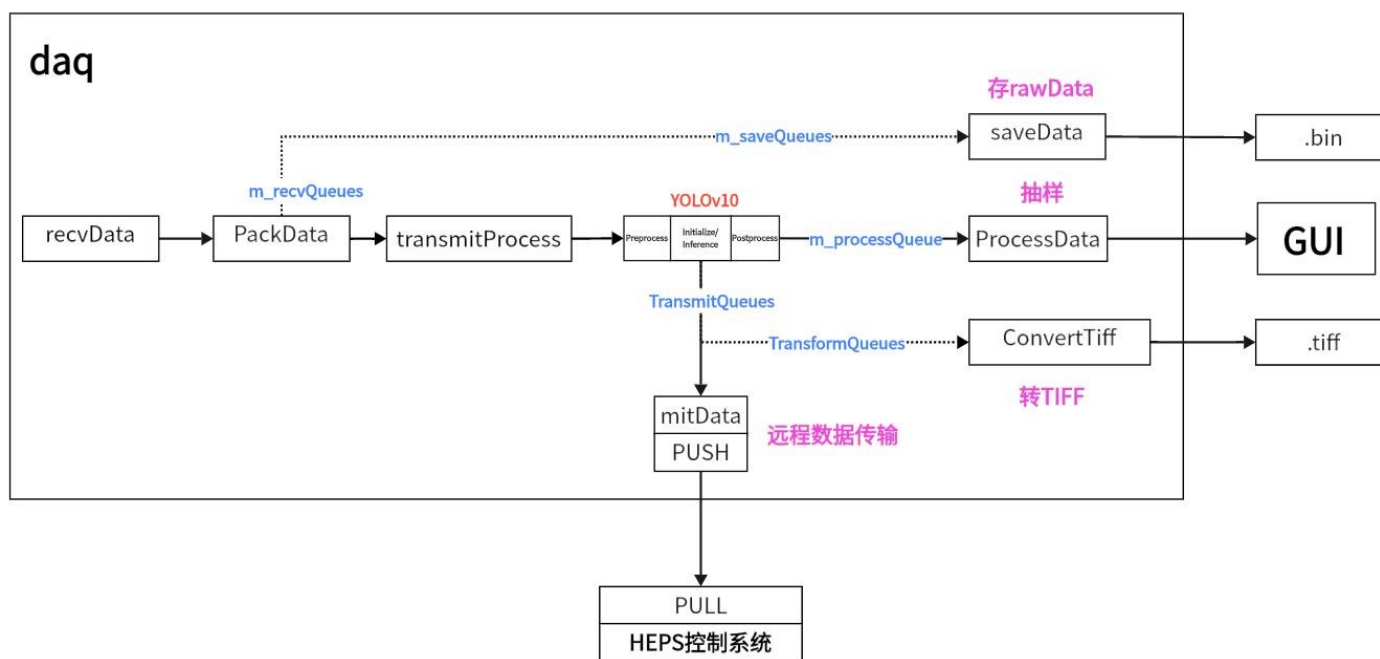
- 实际省略图像生成和读取过程直接将原始数据进行格式对齐输入模型进行推理以提升整体流程性能
- 为了更好地集成如DAQ框架，利用OpenCV库与onnxruntime跨平台引擎用C++重构训练模型的部署



HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究

● HEPS-BPIX4 DAQ框架部署测试

HEPS-BPIX4 DAQ数据流实际部署示意



- 在DAQ数据流框架中，将**预处理**和**后处理**集成在YOLOv10模块中进行，**每40个模块**
单张图像压缩进行一次调用



HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究

● HEPS-BPIX4 DAQ框架部署测试

DAQ框架中单线程处理运行

A40

3ms推理+5ms预处理/后处理

```
ix
300x
0
initialize ok!!
warning!!! the headFlag is not 0x55aa, headFlag:45ac
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 902ms
640 and 640
2896 with 2076
Scaled0.220994
(935,434) and (1938,1458)
Index: 0
duration = 909ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 1004x1025=1029100
crop_mat: 94
crop_mat: 96
crop_mat: 91
warning!!! the headFlag is not 0x55aa, headFlag:45ac
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 3ms
640 and 640
2896 with 2076
Scaled0.220994
(934,435) and (1938,1458)
Index: 0
duration = 10ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 1005x1024=1029120
crop_mat: 83
crop_mat: 92
crop_mat: 89
warning!!! the headFlag is not 0x55aa, headFlag:45ac
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 3ms
640 and 640
2896 with 2076
Scaled0.220994
(939,436) and (1936,1457)
Index: 0
duration = 9ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 999x1022=1029078
crop_mat: 63
crop_mat: 93
crop_mat: 74
warning!!! the headFlag is not 0x55aa, headFlag:45ac
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 3ms
640 and 640
```

A10

3ms推理+5ms预处理/后处理

```
640 and 640
2896 with 2076
Scaled0.220994
(936,436) and (1938,1455)
Index: 0
duration = 8ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 1003x1020=1023060
crop_mat: 74
crop_mat: 85
crop_mat: 92
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 3ms
640 and 640
2896 with 2076
Scaled0.220994
(938,437) and (1936,1456)
Index: 0
duration = 8ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 999x1020=1018980
crop_mat: 97
crop_mat: 92
crop_mat: 65
warning!!! the headFlag is not 0x55aa, headFlag:45ac
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 3ms
640 and 640
2896 with 2076
Scaled0.220994
(937,435) and (1938,1456)
Index: 0
duration = 8ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 1002x1022=1024044
crop_mat: 102
crop_mat: 82
crop_mat: 91
warning!!! the headFlag is not 0x55aa, headFlag:45ac
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 3ms
640 and 640
2896 with 2076
Scaled0.220994
(938,437) and (1936,1457)
Index: 0
duration = 7ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 999x1021=1019979
crop_mat: 91
crop_mat: 107
crop_mat: 105
```

A2

6ms推理+5ms预处理/后处理

```
(937,435) and (1938,1456)
Index: 0
duration = 12ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 1002x1022=1024044
crop_mat: 84
crop_mat: 84
crop_mat: 84
warning!!! the headFlag is not 0x55aa, headFlag:45ac
warning!!! the headFlag is not 0x55aa, headFlag:45ac
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 6ms
640 and 640
2896 with 2076
Scaled0.220994
(937,437) and (1937,1457)
Index: 0
duration = 11ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 1001x1021=1022921
crop_mat: 72
crop_mat: 125
crop_mat: 80
warning!!! the headFlag is not 0x55aa, headFlag:45ac
warning!!! the headFlag is not 0x55aa, headFlag:45ac
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 6ms
640 and 640
2896 with 2076
Scaled0.220994
(933,433) and (1940,1459)
Index: 0
duration = 12ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 1008x1027=1035216
crop_mat: 104
crop_mat: 101
crop_mat: 80
warning!!! the headFlag is not 0x55aa, headFlag:45ac
warning!!! the headFlag is not 0x55aa, headFlag:45ac
Image dimensions: 2076 x 2896
Image_rgb dimensions: 2076 x 2896
inf duration = 6ms
640 and 640
2896 with 2076
Scaled0.220994
(931,434) and (1939,1461)
Index: 0
duration = 11ms
OpenCV version: 4.10.0
inference success!!!
Mat_Size: 1009x1026=1037252
crop_mat: 68
crop_mat: 93
```

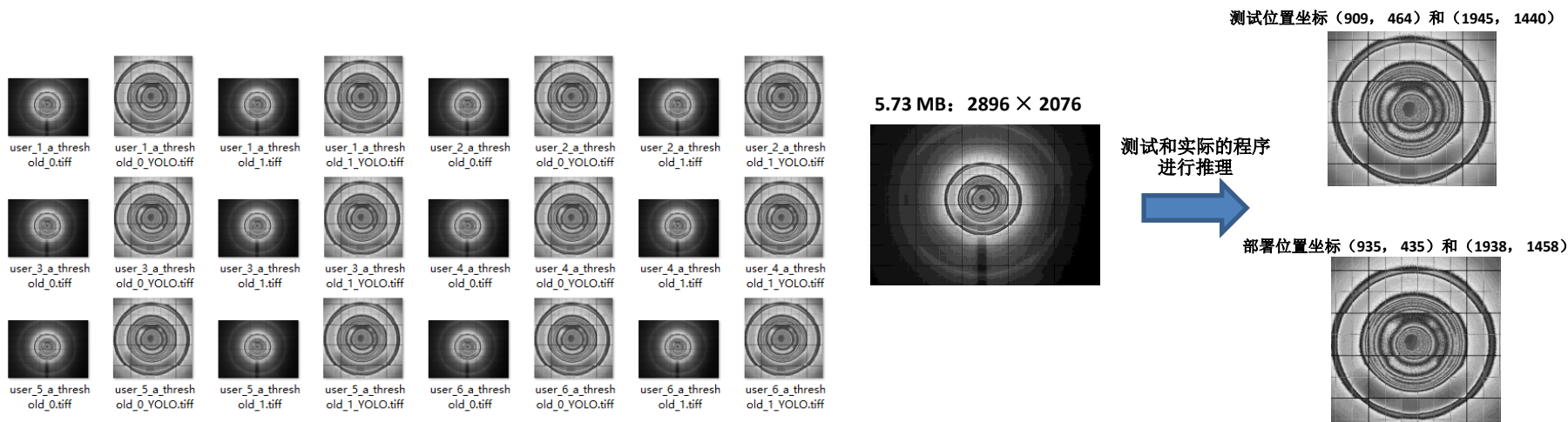
- 在GPU中进行推理过程加速，Nvidia A40和A10显卡中单张图像推理的平均处理延迟平均为3ms，A2显卡的推理延迟平均为6ms，预处理和后处理的延迟为6ms

HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究



● HEPS-BPIX4 DAQ框架部署测试

识别剪切处理效果测试



- 12张测试数据识别率100%，图像大小平均压缩至原来的17%，准确度符合测试预期

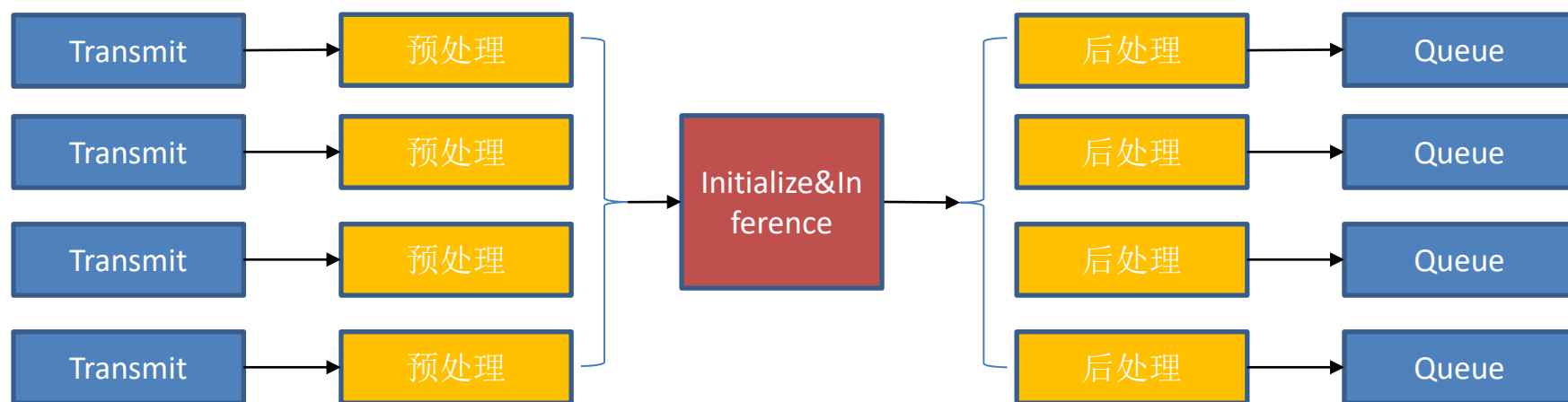


HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究

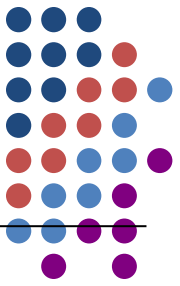
● HEPS-BPIX4 DAQ框架部署测试

HEPS-BPIX4 DAQ数据流部署示意

DAQ框架中多线程处理运行



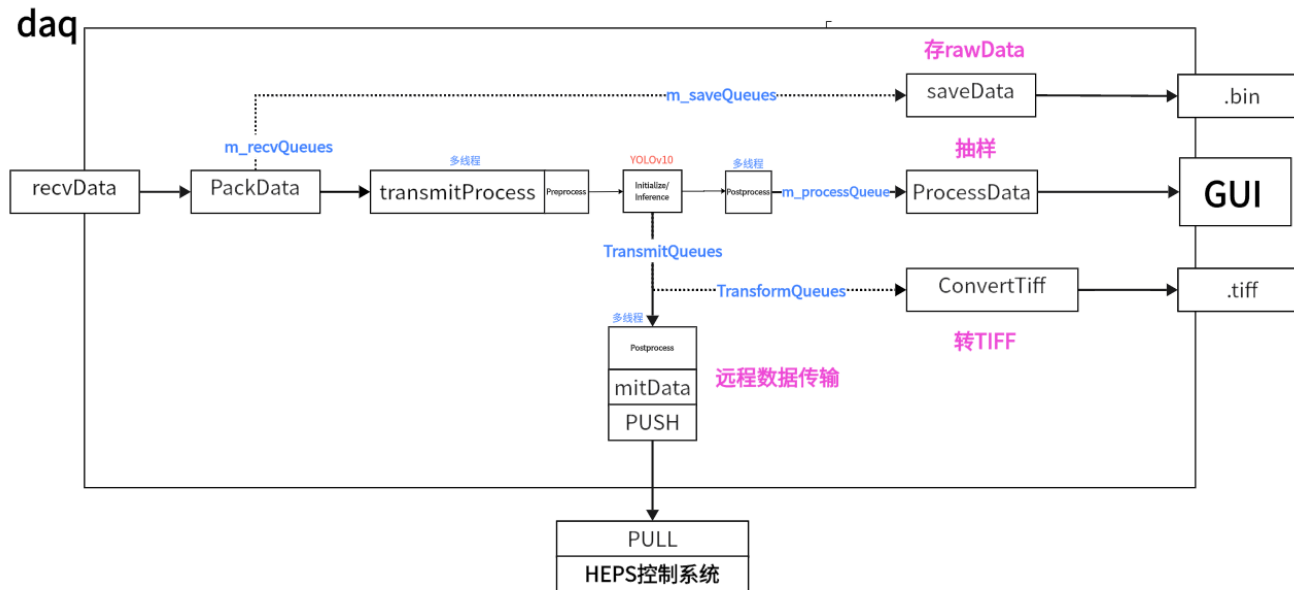
- 为了覆盖预处理及后处理的开销，设计一种新的处理模式，利用CPU多核通过多线程进行处理，使理想情况下的单张图像预处理和后处理延迟变为 $3/N$ ms，N为线程数，且能充分利用CPU的资源



HEPS-BPIX4 DAQ基于机器学习目标检测的在线图像数据压缩研究

● HEPS-BPIX4 DAQ框架部署测试

HEPS-BPIX4 DAQ数据流实际部署示意



- 后续实现与测试正在开展进行

THANK YOU !

