

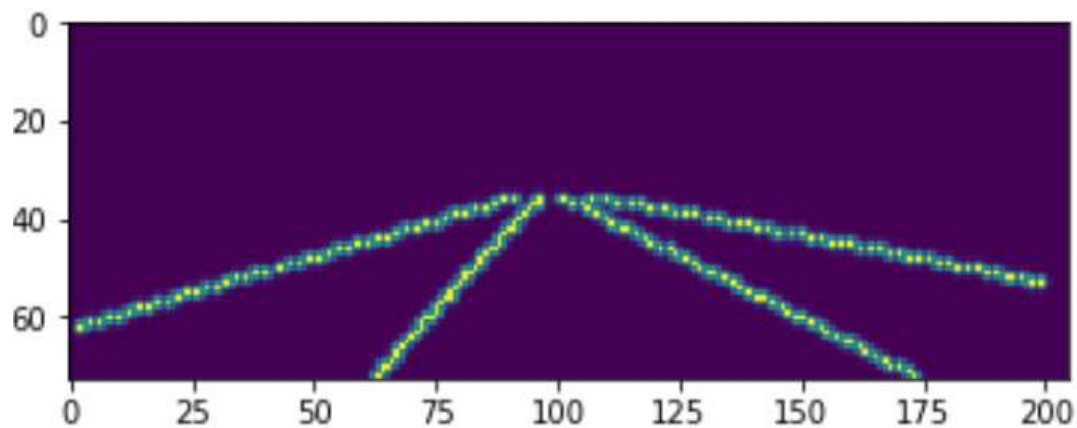
# A Keypoint-based Global Association Network for Lane Detection

简称GANet

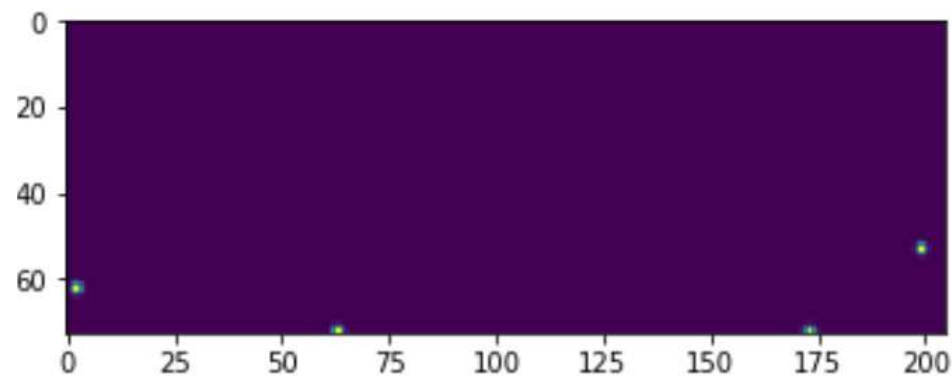
By zhangyunzhi

# GANet训练标签

- 1、使用三次B样条回归出车道线
- 2、均匀取45个点，并以它们为中心做高斯掩码 (**kernel=5**)

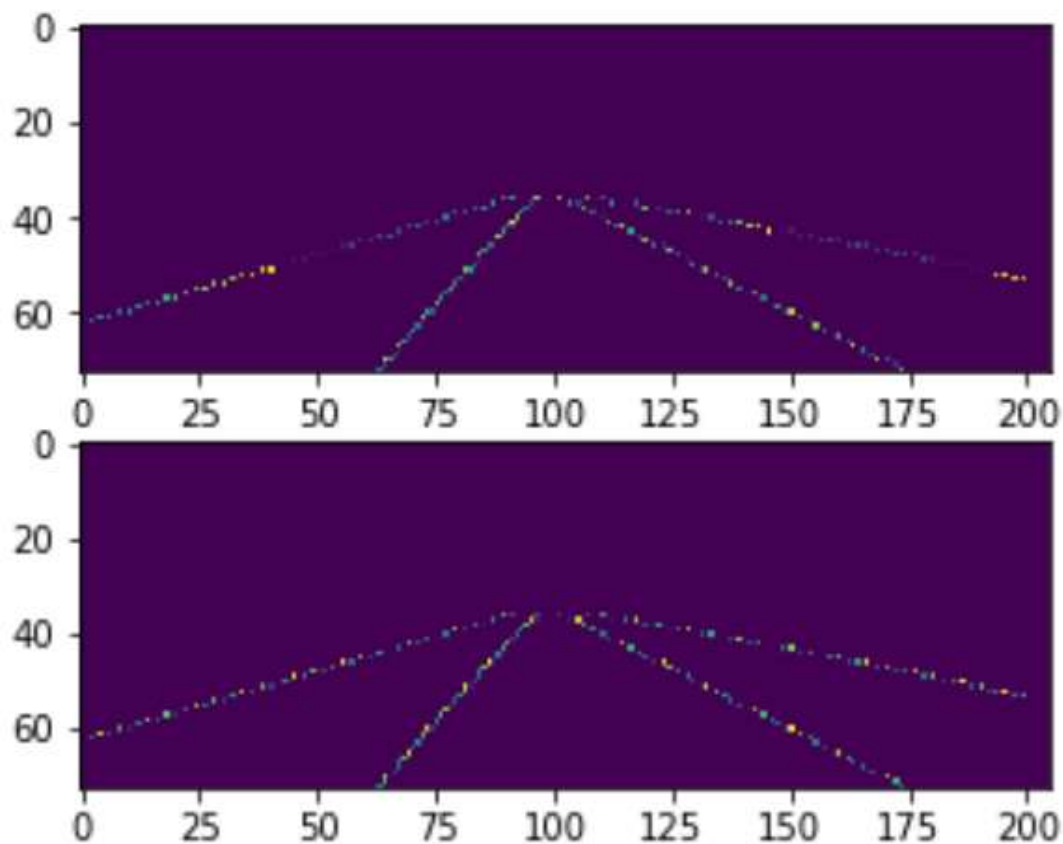


左图：关键点的heat map



右图：车道线起始点的heat map，用于聚类

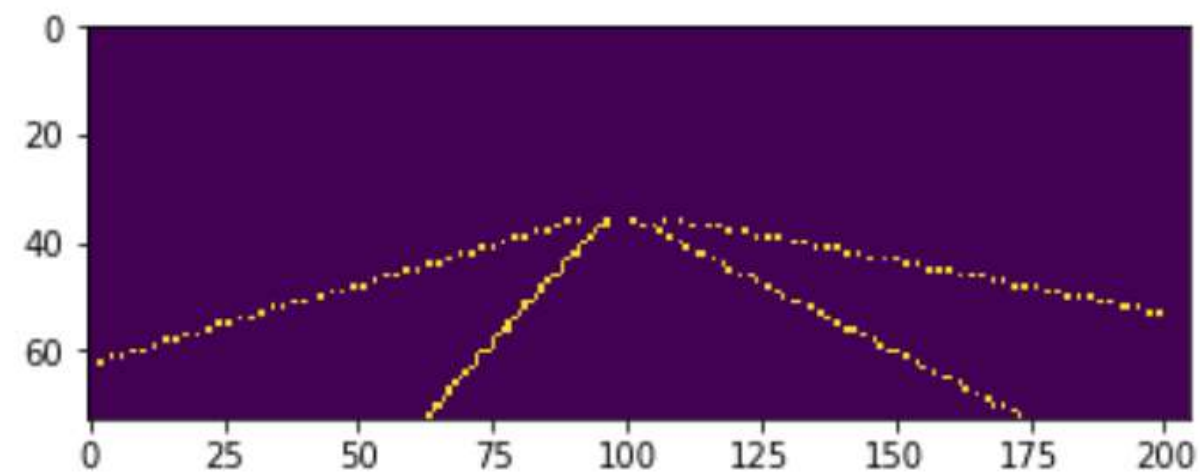
## Error: 误差图



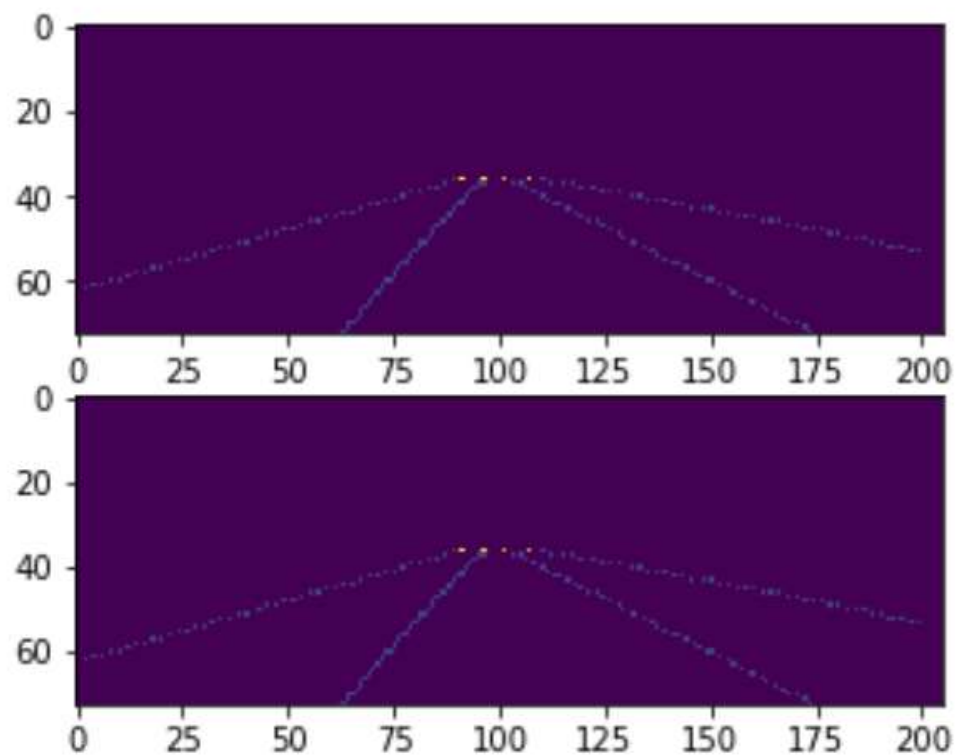
Label给定关键点坐标都是float类型  
这个热力图用于对齐整数和float类型的坐标存在误差

```
1 240.573 590 257.848 580 275.127 570 292.409 560 309.699 550 327.126 540 344.573 530 361.848 520 375.127 510 387.409 500 392.409 490 409.699 480 427.126 470 444.573 460 461.848 450 475.127 440 487.409 430 492.409 420 509.699 410 527.126 400 544.573 390 561.848 380 575.127 370 587.409 360 592.409 350 609.699 340 627.126 330 644.573 320 661.848 310 675.127 300 687.409 290 692.409 280 709.699 270 727.126 260 744.573 250 761.848 240 775.127 230 787.409 220 792.409 210 809.699 200 827.126 190 844.573 180 861.848 170 875.127 160 887.409 150 892.409 140 909.699 130 927.126 120 944.573 110 961.848 100 975.127 90 987.409 80 992.409 70 1009.699 60 1027.126 50 1044.573 40 1061.848 30 1075.127 20 1087.409 10 1092.409 0 1109.699 1106.848 590 1123.33 580 1140.99 570 1158.67 560 1177.02 550 1194.72 540 1210.7 530 1227.02 520 1242.69 510 1257.33 500 1271.66 490 1285.66 480 1299.33 470 1312.66 460 1325.66 450 1338.33 440 1350.66 430 1362.66 420 1374.33 410 1385.66 400 1396.66 390 1407.33 380 1417.66 370 1427.66 360 1437.33 350 1447.33 340 1457.33 330 1467.33 320 1477.33 310 1487.33 300 1497.33 290 1507.33 280 1517.33 270 1527.33 260 1537.33 250 1547.33 240 1557.33 230 1567.33 220 1577.33 210 1587.33 200 1597.33 190 1607.33 180 1617.33 170 1627.33 160 1637.33 150 1647.33 140 1657.33 130 1667.33 120 1677.33 110 1687.33 100 1697.33 90 1707.33 80 1717.33 70 1727.33 60 1737.33 50 1747.33 40 1757.33 30 1767.33 20 1777.33 10 1787.33 0 1797.33 1707.33 590 1723.33 580 1740.99 570 1758.67 560 1777.02 550 1794.72 540 1810.7 530 1827.02 520 1842.69 510 1857.33 500 1871.66 490 1885.66 480 1899.33 470 1912.66 460 1925.66 450 1938.33 440 1950.66 430 1962.66 420 1974.33 410 1985.66 400 1996.66 390 2007.33 380 2017.33 370 2027.33 360 2037.33 350 2047.33 340 2057.33 330 2067.33 320 2077.33 310 2087.33 300 2097.33 290 2107.33 280 2117.33 270 2127.33 260 2137.33 250 2147.33 240 2157.33 230 2167.33 220 2177.33 210 2187.33 200 2197.33 190 2207.33 180 2217.33 170 2227.33 160 2237.33 150 2247.33 140 2257.33 130 2267.33 120 2277.33 110 2287.33 100 2297.33 90 2307.33 80 2317.33 70 2327.33 60 2337.33 50 2347.33 40 2357.33 30 2367.33 20 2377.33 10 2387.33 0 2397.33 2207.33 590 2223.33 580 2240.99 570 2258.67 560 2277.02 550 2294.72 540 2310.7 530 2327.02 520 2342.69 510 2357.33 500 2371.66 490 2385.66 480 2399.33 470 2412.66 460 2425.66 450 2438.33 440 2450.66 430 2462.66 420 2474.33 410 2485.66 400 2496.66 390 2507.33 380 2517.33 370 2527.33 360 2537.33 350 2547.33 340 2557.33 330 2567.33 320 2577.33 310 2587.33 300 2597.33 290 2607.33 280 2617.33 270 2627.33 260 2637.33 250 2647.33 240 2657.33 230 2667.33 220 2677.33 210 2687.33 200 2697.33 190 2707.33 180 2717.33 170 2727.33 160 2737.33 150 2747.33 140 2757.33 130 2767.33 120 2777.33 110 2787.33 100 2797.33 90 2807.33 80 2817.33 70 2827.33 60 2837.33 50 2847.33 40 2857.33 30 2867.33 20 2877.33 10 2887.33 0 2897.33 2707.33 590 2723.33 580 2740.99 570 2758.67 560 2777.02 550 2794.72 540 2810.7 530 2827.02 520 2842.69 510 2857.33 500 2871.66 490 2885.66 480 2899.33 470 2912.66 460 2925.66 450 2938.33 440 2950.66 430 2962.66 420 2974.33 410 2985.66 400 2996.66 390 3007.33 380 3017.33 370 3027.33 360 3037.33 350 3047.33 340 3057.33 330 3067.33 320 3077.33 310 3087.33 300 3097.33 290 3107.33 280 3117.33 270 3127.33 260 3137.33 250 3147.33 240 3157.33 230 3167.33 220 3177.33 210 3187.33 200 3197.33 190 3207.33 180 3217.33 170 3227.33 160 3237.33 150 3247.33 140 3257.33 130 3267.33 120 3277.33 110 3287.33 100 3297.33 90 3307.33 80 3317.33 70 3327.33 60 3337.33 50 3347.33 40 3357.33 30 3367.33 20 3377.33 10 3387.33 0 3397.33 3207.33 590 3223.33 580 3240.99 570 3258.67 560 3277.02 550 3294.72 540 3310.7 530 3327.02 520 3342.69 510 3357.33 500 3371.66 490 3385.66 480 3399.33 470 3412.66 460 3425.66 450 3438.33 440 3450.66 430 3462.66 420 3474.33 410 3485.66 400 3496.66 390 3507.33 380 3517.33 370 3527.33 360 3537.33 350 3547.33 340 3557.33 330 3567.33 320 3577.33 310 3587.33 300 3597.33 290 3607.33 280 3617.33 270 3627.33 260 3637.33 250 3647.33 240 3657.33 230 3667.33 220 3677.33 210 3687.33 200 3697.33 190 3707.33 180 3717.33 170 3727.33 160 3737.33 150 3747.33 140 3757.33 130 3767.33 120 3777.33 110 3787.33 100 3797.33 90 3807.33 80 3817.33 70 3827.33 60 3837.33 50 3847.33 40 3857.33 30 3867.33 20 3877.33 10 3887.33 0 3897.33 3507.33 590 3523.33 580 3540.99 570 3558.67 560 3577.02 550 3594.72 540 3610.7 530 3627.02 520 3642.69 510 3657.33 500 3671.66 490 3685.66 480 3699.33 470 3712.66 460 3725.66 450 3738.33 440 3750.66 430 3762.66 420 3774.33 410 3785.66 400 3796.66 390 3807.33 380 3817.33 370 3827.33 360 3837.33 350 3847.33 340 3857.33 330 3867.33 320 3877.33 310 3887.33 300 3897.33 290 3907.33 280 3917.33 270 3927.33 260 3937.33 250 3947.33 240 3957.33 230 3967.33 220 3977.33 210 3987.33 200 3997.33 190 4007.33 180 4017.33 170 4027.33 160 4037.33 150 4047.33 140 4057.33 130 4067.33 120 4077.33 110 4087.33 100 4097.33 90 4107.33 80 4117.33 70 4127.33 60 4137.33 50 4147.33 40 4157.33 30 4167.33 20 4177.33 10 4187.33 0 4197.33 3807.33 590 3723.33 580 3740.99 570 3758.67 560 3777.02 550 3794.72 540 3810.7 530 3827.02 520 3842.69 510 3857.33 500 3871.66 490 3885.66 480 3899.33 470 3912.66 460 3925.66 450 3938.33 440 3950.66 430 3962.66 420 3974.33 410 3985.66 400 3996.66 390 4007.33 380 4017.33 370 4027.33 360 4037.33 350 4047.33 340 4057.33 330 4067.33 320 4077.33 310 4087.33 300 4097.33 290 4107.33 280 4117.33 270 4127.33 260 4137.33 250 4147.33 240 4157.33 230 4167.33 220 4177.33 210 4187.33 200 4197.33 190 4207.33 180 4217.33 170 4227.33 160 4237.33 150 4247.33 140 4257.33 130 4267.33 120 4277.33 110 4287.33 100 4297.33 90 4307.33 80 4317.33 70 4327.33 60 4337.33 50 4347.33 40 4357.33 30 4367.33 20 4377.33 10 4387.33 0 4397.33 4107.33 590 3923.33 580 3940.99 570 3958.67 560 3977.02 550 3994.72 540 4010.7 530 4027.02 520 4042.69 510 4057.33 500 4071.66 490 4085.66 480 4099.33 470 4112.66 460 4125.66 450 4138.33 440 4150.66 430 4162.66 420 4174.33 410 4185.66 400 4196.66 390 4207.33 380 4217.33 370 4227.33 360 4237.33 350 4247.33 340 4257.33 330 4267.33 320 4277.33 310 4287.33 300 4297.33 290 4307.33 280 4317.33 270 4327.33 260 4337.33 250 4347.33 240 4357.33 230 4367.33 220 4377.33 210 4387.33 200 4397.33 190 4407.33 180 4417.33 170 4427.33 160 4437.33 150 4447.33 140 4457.33 130 4467.33 120 4477.33 110 4487.33 100 4497.33 90 4507.33 80 4517.33 70 4527.33 60 4537.33 50 4547.33 40 4557.33 30 4567.33 20 4577.33 10 4587.33 0 4597.33 4407.33 590 4123.33 580 4140.99 570 4158.67 560 4177.02 550 4194.72 540 4210.7 530 4227.02 520 4242.69 510 4257.33 500 4271.66 490 4285.66 480 4299.33 470 4312.66 460 4325.66 450 4338.33 440 4350.66 430 4362.66 420 4374.33 410 4385.66 400 4396.66 390 4407.33 380 4417.33 370 4427.33 360 4437.33 350 4447.33 340 4457.33 330 4467.33 320 4477.33 310 4487.33 300 4497.33 290 4507.33 280 4517.33 270 4527.33 260 4537.33 250 4547.33 240 4557.33 230 4567.33 220 4577.33 210 4587.33 200 4597.33 190 4607.33 180 4617.33 170 4627.33 160 4637.33 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510 4657.33 500 4671.66 490 4685.66 480 4699.33 470 4712.66 460 4725.66 450 4738.33 440 4750.66 430 4762.66 420 4774.33 410 4785.66 400 4796.66 390 4807.33 380 4817.33 370 4827.33 360 4837.33 350 4847.33 340 4857.33 330 4867.33 320 4877.33 310 4887.33 300 4897.33 290 4907.33 280 4917.33 270 4927.33 260 4937.33 250 4947.33 240 4957.33 230 4967.33 220 4977.33 210 4987.33 200 4997.33 190 5007.33 180 5017.33 170 5027.33 160 5037.33 150 5047.33 140 5057.33 130 5067.33 120 5077.33 110 5087.33 100 5097.33 90 5107.33 80 5117.33 70 5127.33 60 5137.33 50 5147.33 40 5157.33 30 5167.33 20 5177.33 10 5187.33 0 5197.33 5307.33 590 4723.33 580 4740.99 570 4758.67 560 4777.02 550 4794.72 540 4810.7 530 4827.02 520 4842.69 510 4857.33 500 4871.66 490 4885.66 480 4899.33 470 4912.66 460 4925.66 450 4938.33 440 4950.66 430 4962.66 420 4974.33 410 4985.66 400 4996.66 390 5007.33 380 5017.33 370 5027.33 360 5037.33 350 5047.33 340 5057.33 330 5067.33 320 5077.33 310 5087.33 300 5097.33 290 5107.33 280 5117.33 270 5127.33 260 5137.33 250 5147.33 240 5157.33 230 5167.33 220 5177.33 210 5187.33 200 5197.33 190 5207.33 180 5217.33 170 5227.33 160 5237.33 150 5247.33 140 5257.33 130 5267.33 120 5277.33 110 5287.33 100 5297.33 90 5307.33 80 5317.33 70 5327.33 60 5337.33 50 5347.33 40 5357.33 30 5367.33 20 5377.33 10 5387.33 0 5397.33 5607.33 590 4923.33 580 4940.99 570 4958.67 560 4977.02 550 4994.72 540 5010.7 530 5027.02 520 5042.69 510 5057.33 500 5071.66 490 5085.66 480 5099.33 470 5112.66 460 5125.66 450 5138.33 440 5150.66 430 5162.66 420 5174.33 410 5185.66 400 5196.66 390 5207.33 380 5217.33 370 5227.33 360 5237.33 350 5247.33 340 5257.33 330 5267.33 320 5277.33 310 5287.33 300 5297.33 290 5307.33 280 5317.33 270 5327.33 260 5337.33 250 5347.33 240 5357.33 230 5367.33 220 5377.33 210 5387.33 200 5397.33 190 5407.33 180 5417.33 170 5427.33 160 5437.33 150 5447.33 140 5457.33 130 5467.33 120 5477.33 110 5487.33 100 5497.33 90 5507.33 80 5517.33 70 5527.33 60 5537.33 50 5547.33 40 5557.33 30 5567.33 20 5577.33 10 5587.33 0 5597.33 5907.33 590 5123.33 580 5140.99 570 5158.67 560 5177.02 550 5194.72 540 5210.7 530 5227.02 520 5242.69 510 5257.33 500 5271.66 490 5285.66 480 5299.33 470 5312.66 460 5325.66 450 5338.33 440 5350.66 430 5362.66 420 5374.33 410 5385.66 400 5396.66 390 5407.33 380 5417.33 370 5427.33 360 5437.33 350 5447.33 340 5457.33 330 5467.33 320 5477.33 310 5487.33 300 5497.33 290 5507.33 280 5517.33 270 5527.33 260 5537.33 250 5547.33 240 5557.33 230 5567.33 220 5577.33 210 5587.33 200 5597.33 190 5607.33 180 5617.33 170 5627.33 160 5637.33 150 5647.33 140 5657.33 130 5667.33 120 5677.33 110 5687.33 100 5697.33 90 5707.33 80 5717.33 70 5727.33 60 5737.33 50 5747.33 40 5757.33 30 5767.33 20 5777.33 10 5787.33 0 5797.33 6207.33 590 5323.33 580 5340.99 570 5358.67 560 5377.02 550 5394.72 540 5410.7 530 5427.02 520 5442.69 510 5457.33 500 5471.66 490 5485.66 480 5499.33 470 5512.66 460 5525.66 450 5538.33 440 5550.66 430 5562.66 420 5574.33 410 5585.66 400 5596.66 390 5607.33 380 5617.33 370 5627.33 360 5637.33 350 5647.33 340 5657.33 330 5667.33 320 5677.33 310 5687.33 300 5697.33 290 5707.33 280 5717.33 270 5727.33 260 5737.33 250 5747.33 240 5757.33 230 5767.33 220 5777.33 210 5787.33 200 5797.33 190 5807.33 180 5817.33 170 5827.33 160 5837.33 150 5847.33 140 5857.33 130 5867.33 120 5877.33 110 5887.33 100 5897.33 90 5907.33 80 5917.33 70 5927.33 60 5937.33 50 5947.33 40 5957.33 30 5967.33 20 5977.33 10 5987.33 0 5997.33 6507.33 590 5523.33 580 5540.99 570 5558.67 560 5577.02 550 5594.72 540 5610.7 530 5627.02 520 5642.69 510 5657.33 500 5671.66 490 5685.66 480 5699.33 470 5712.66 460 5725.66 450 5738.33 440 5750.66 430 5762.66 420 5774.33 410 5785.66 400 5796.66 390 5807.33 380 5817.33 370 5827.33 360 5837.33 350 5847.33 340 5857.33 330 5867.33 320 5877.33 310 5887.33 300 5897.33 290 5907.33 280 5917.33 270 5927.33 260 5937.33 250 5947.33 240 5957.33 230 5967.33 220 5977.33 210 5987.33 200 5997.33 190 6007.33 180 6017.33 170 6027.33 160 6037.33 150 6047.
```

# 车道线掩码和消失点加权掩码(training)

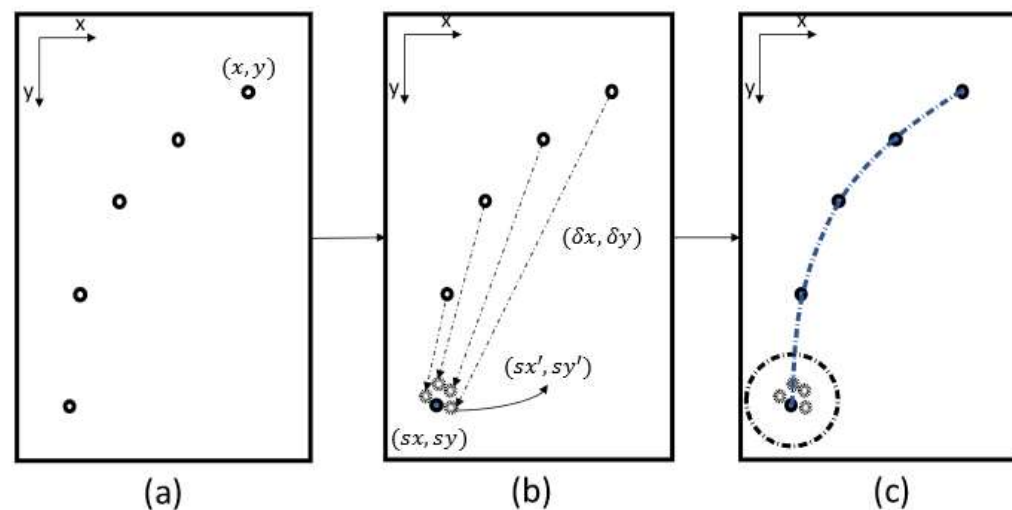
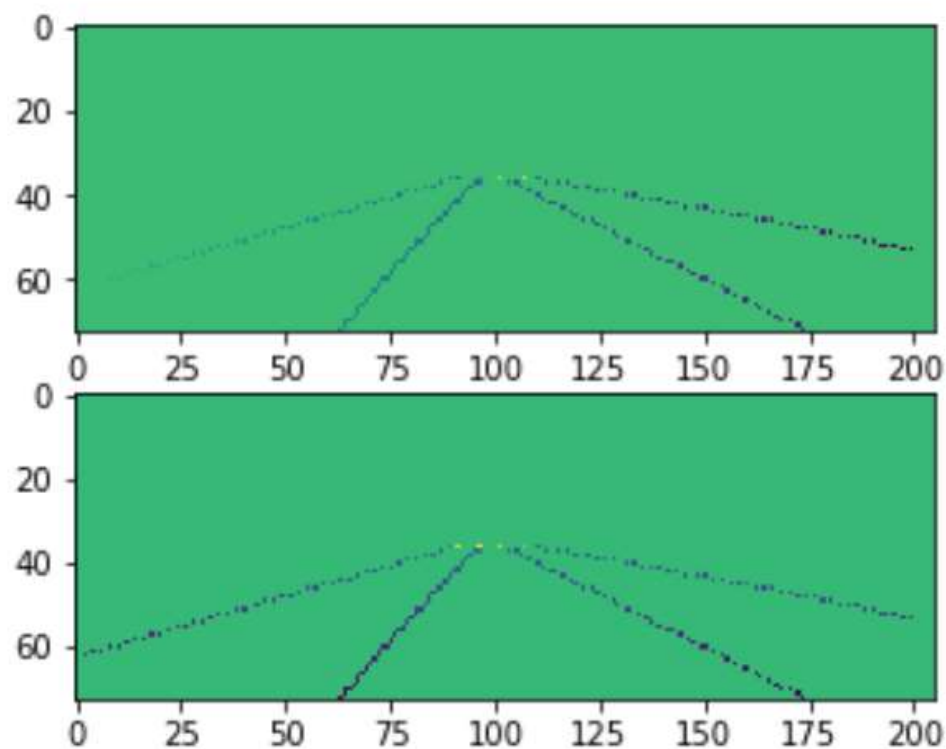


普通掩码：整数关键点处为1



加权掩码：给消失点加权

# 车道线起始点的偏移量



使用起始点聚类

# 掩码L1loss: 用于预测offset和error

```
def forward(self, output, target, mask):  
    loss = F.l1_loss(output * mask, target * mask, size_average=False)  
    mask = mask.bool().float()  
    loss = loss / (mask.sum() + 1e-4)  
    return loss
```

## 使用掩码加权的l1 loss

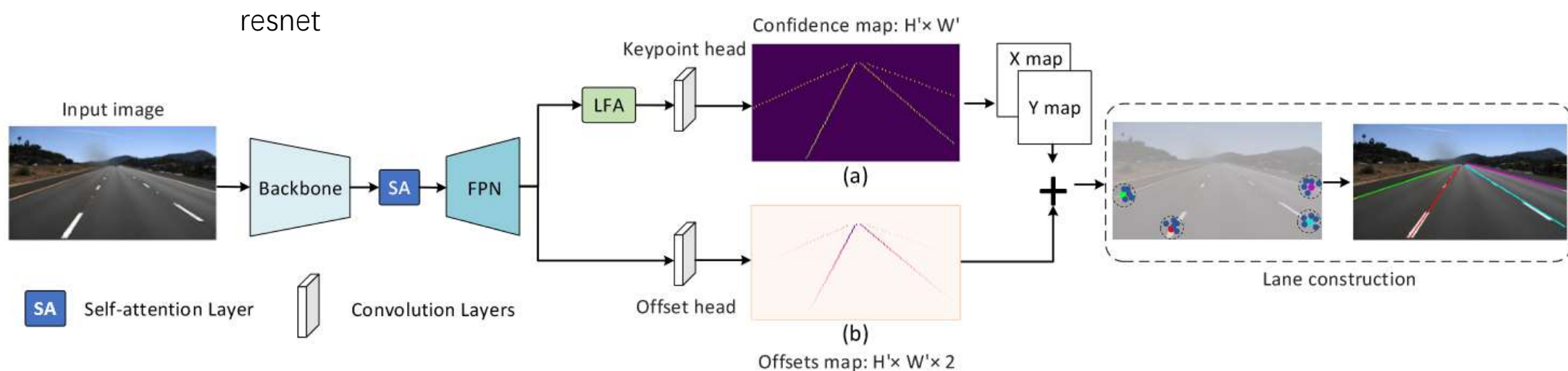
用于**error map**(掩码为正常mask)和**offset map**(掩码为加权掩码)

使用mask会使loss更加稳定，防止前景背景分布不均

而key point heat map和start point heat map (权重为0? ) 用focal loss

# 网络结构:

- 多个**解耦的头**部分别预测热力图、偏移量图和误差图
- FPN结构, 但是, 最终输出时, 每一层过一遍**dcn**
- Self-attention: 仅用于FPN下**采样最多**的输出
- 推理时,  $\text{abs}(\text{offset}) < 1$ 是**候选起始点**



# LanePointConv:

**B:** batch\_size

**DCN:** deformable CNN 1D

**Kernel\_sz:** in [(1,7),(1,5),(1,3)]

**Detach:** to detach grad by 90%

integrated with a deformable convolution to aggregate context of the  $i$ -th keypoint as:

$$\hat{\mathcal{F}}(p_i) = \sum_{m=1}^M w_m \cdot \mathcal{F}(p_i + \Delta p_i^m), \quad (9)$$

where  $w_m, m = 1, \dots, M$  is the weight of the convolution and  $(\cdot)$  means multiplication.

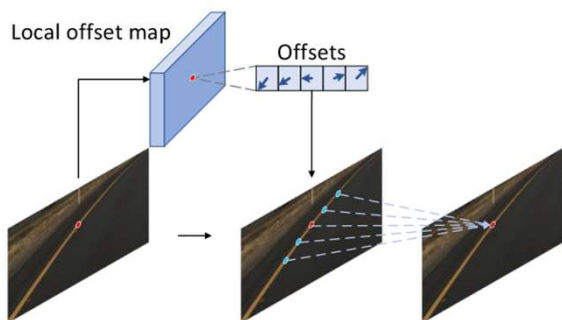
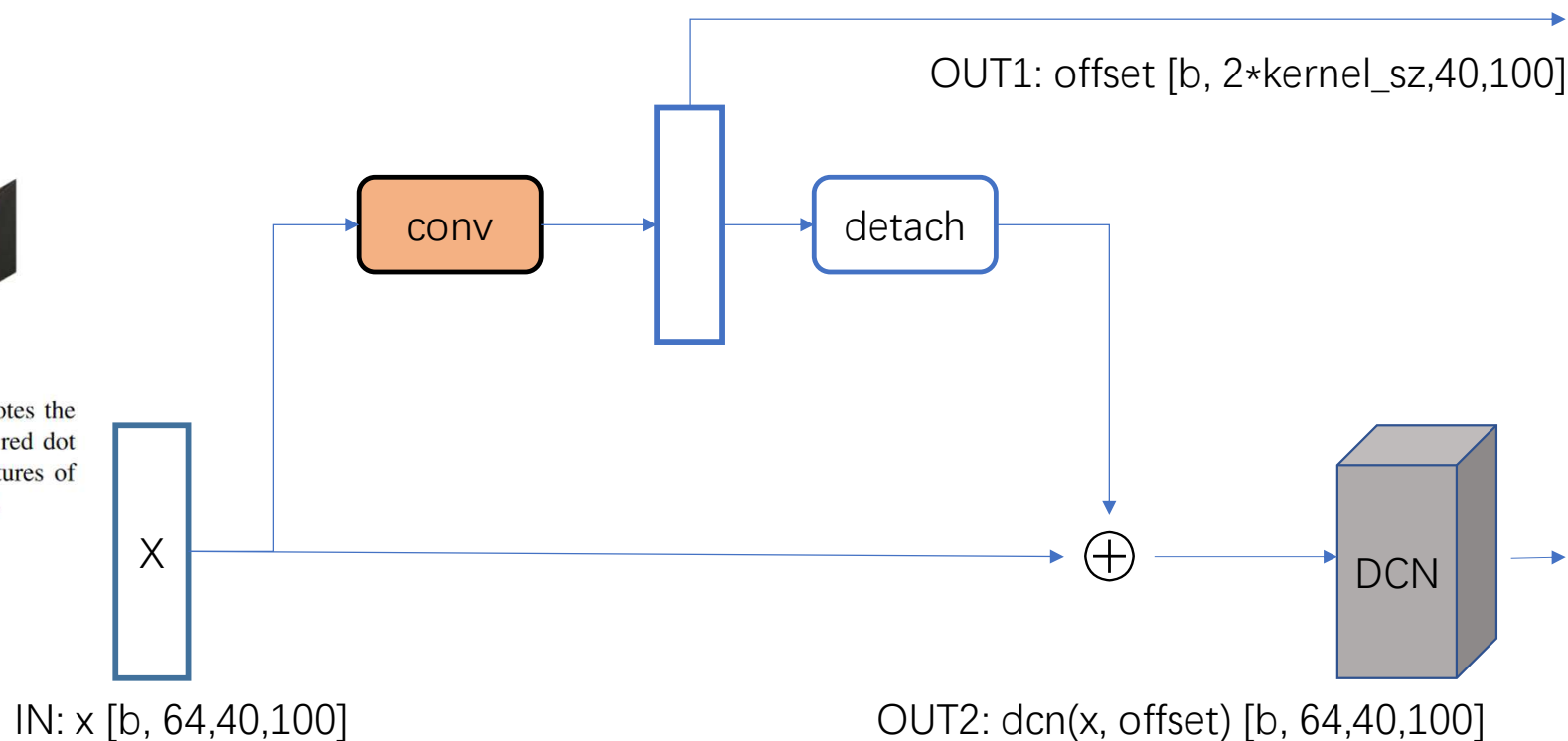


Figure 4. Illustration of LFA module. The red dot denotes the observed keypoint. We first predict offsets between the red dot and its adjacent keypoints (in blue) and then gather features of these keypoints to enhance the context of the red keypoint.





INPUT from backbone:

[b,128,40,100]

[b,256,20,50]

[b,512,10,25]

### Projection Layer:

conv1x1

conv1x1

conv1x1

[b,64,40,100]

[b,64,20,50]

[b,64,10,25]

identity

## LanePointConv

[b,64,40,100]

aux\_feature

[b,14,40,100]

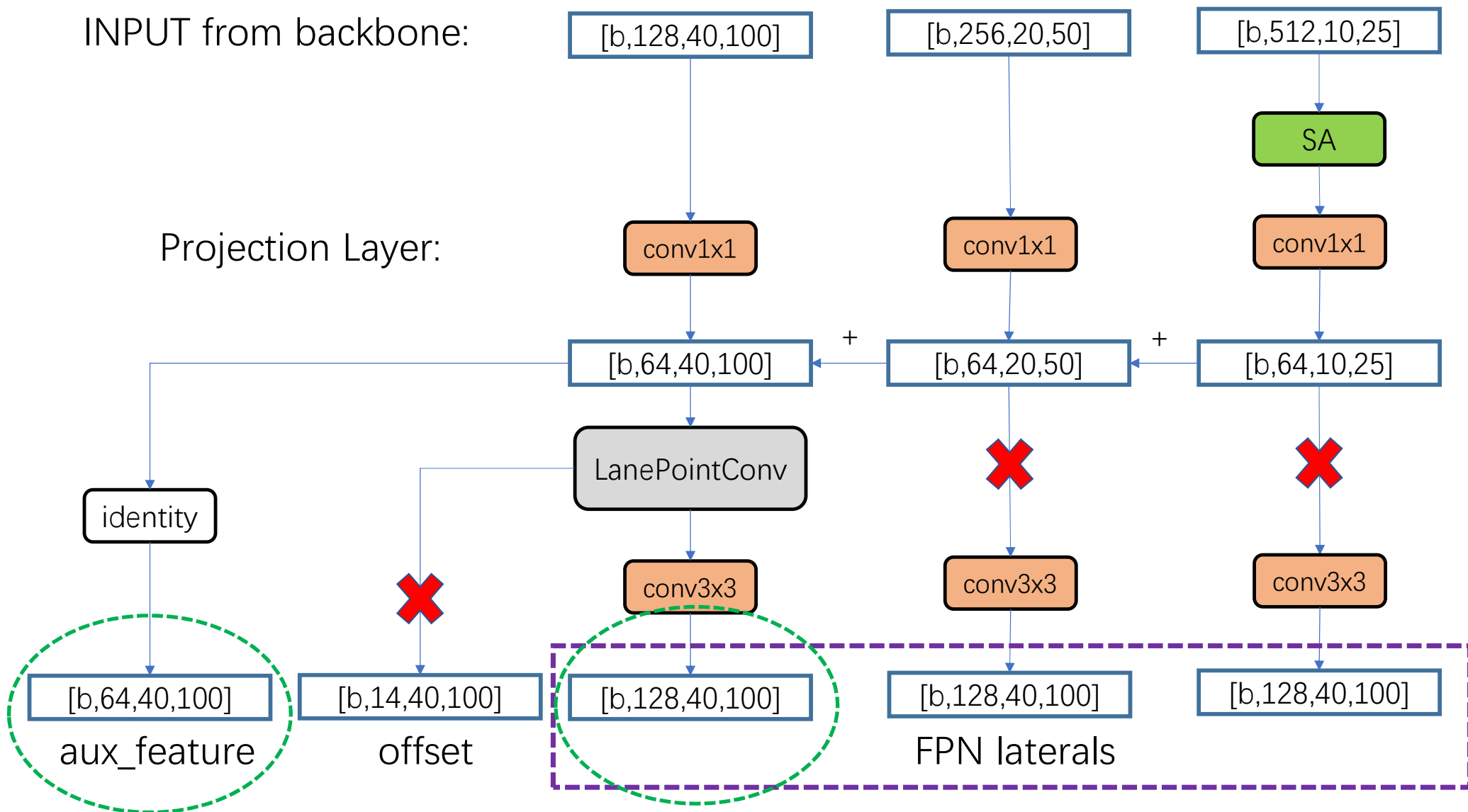
offset

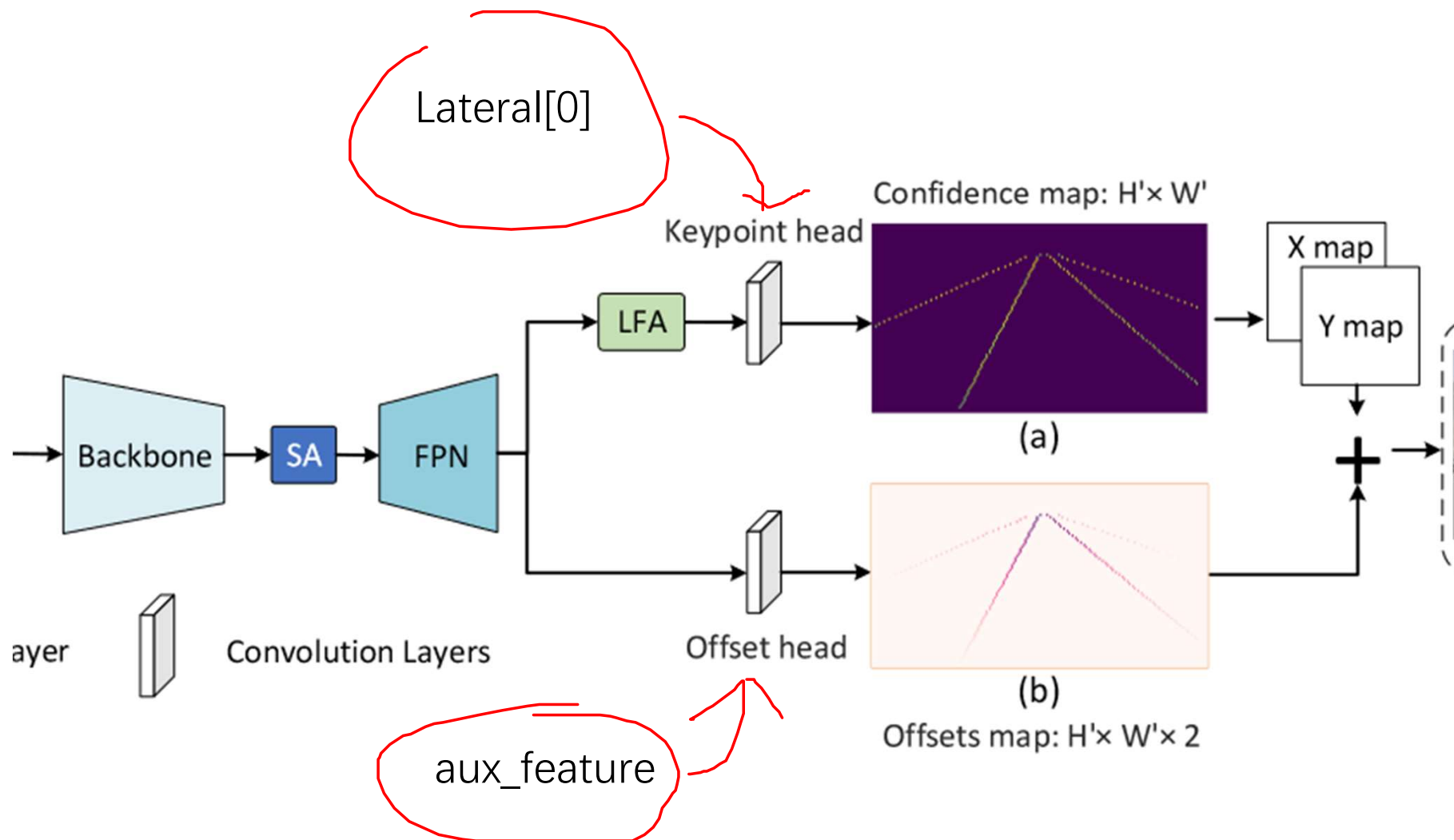
[b,128,40,100]

[b,128,40,100]

## FPN laterals

[b,128,40,100]





# 推理

- 起始点

$(\text{heat\_map} > 0.3) * (\text{offset} < 1)$ 取均值

- 关键点:

$\text{heat\_map}[\text{offset} + \text{meshgrid2d}]$  where  $\text{heat\_map} > 0.3$

然后计算和起始点的距离使用KNN算法聚类

$$(sx', sy') = (x, y) + (\delta x, \delta y), \quad (7)$$

where  $(x, y)$  is the coordinate of the observed keypoint and  $(\delta x, \delta y) = O_{yx}$  denotes the corresponding offset obtained in Section 3.1.2. The keypoint  $(x, y)$  is associated to the  $i$ -th lane only if the distance between  $(sx', sy')$  and  $(sx, sy)$  is less than a predefined threshold  $\theta_{dis}$ . As shown in Fig-

$= 5$

hm:[1, 1, 40, 100] from key point head 热力图

offset:[1,2,40,100] from offset head 坐标偏移量且为y offset

error: [1,2,40,100] from error head 把关键点从整数值修正到浮点数

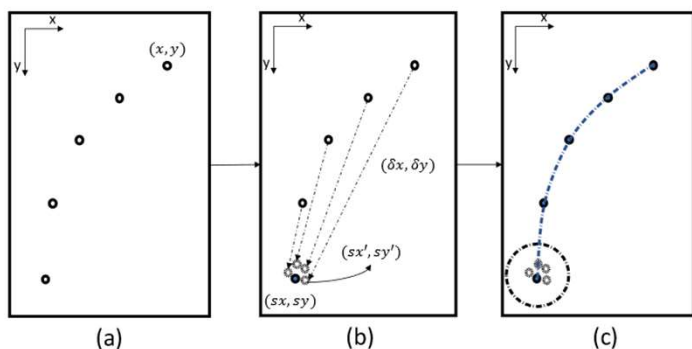


Figure 3. Illustration of lane construction. (a) Valid keypoints are selected from the confidence map.  $(x, y)$  is taken as an example. (b) Starting point  $(sx, sy)$  (blue dot) is sampled first. The rest keypoints point to the starting point with the predicted offset  $(\delta x, \delta y)$  and estimate the coordinate of the starting points as  $(sx', sy') = (x, y) + (\delta x, \delta y)$  (hollow dots). (c) Keypoints that point to the neighbourhood of starting point  $(sx, sy)$  are grouped as a whole lane.

```
key_points = (meshgrid+error)[where(nms(hm)) > 0.3]
start_points = (meshgrid+offset)[where(nms(hm) > 0.3)]
```

$\text{id}(x,y)$ : which group the point  $(x, y)$  belonging to  
base case: group = [  $[(x_0, y_0)]$  ]

```
for (x, y) in start_points:
    for (cx, cy) in group.flatten():
        if |(x,y) - (cx, cy)| < 5 # 欧式距离小于5
            id(x,y) = id(cx,cy) # (x,y) 的group_id为(cx,cy)的group_id
            group[id] += (x,y) # id对应的group添加新的点
            break inner loop
    if GROUP_NOT_FOUND:
        group += [(x,y)] # 产生一个新的group
```

# 注意到key\_points和start\_points是对齐的, 因此:

```
[id(x,y) for (x,y) in key_points] == [id(sx,sy) for (sx,sy) in start_points]
```