CS6135 VLSI Physical Design Automation

Homework 4: Global Placement

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A. **The wirelength and the runtime of each testcase**

testcase	Wirelength	Runtime
Public1	71741249	37.43
Public2	16280658	86.07
Public3	500524648	151.51

B. **The details of your algorithm. You could use flow chart(s) and/or pseudo code to help elaborate your algorithm. If your method is similar to some previous work/papers, please cite the papers and reveal your difference(s).**

從老師的 slides 中發現 objective function 為

$$\text{minimize} \sum_{e \in E} c_e \times \text{WL}_e(x, y) + \lambda \sum_{b \in B} (D_b(x, y) - T_b)^2$$

而它的 High level 的觀念可以用以下 pseudo code 描述

```
void objective(){
    f = 0.0;
    // Log-Sum-Exponential
    for (net in _placement)
        for (module in net)
            get sum of xMax: xMaxSum;
            get sum of xMin: xMinSum;
            get sum of yMax: yMaxSum;
            get sum of yMin: yMinSum;

        f += lambda * (
                log(xMaxSum) +
                log(xMinSum) +
                log(yMaxSum) +
                log(yMinSum)
            );

    // density (Bell-shape)
    binDensity = [0...0];

    for (b in Bins)
        for (module in _placement)
            if (module is not fixed)
                b += bellShapeFunc(module, b);
        f += lambda * (b - tarDensity)^2;
}
```

其中 bellShapeFunc 為估計 density 的 function:

$$D_b(x, y) = \sum_{i \in V} C_i \times \widetilde{\Theta}_x(b, i) \times \widetilde{\Theta}_y(b, i)$$

2.

$$\widetilde{\Theta}_x(b,i) =$$

➢ $a \times d_x^2 \, if \le d_x \le w_b/2 + w_i/2$

➢ $b \times (d_x - w_b - w_i/2)^2 if w_b/2 + w_i/2 \le d_x \le w_b + w_i/2$

➢ $0 \, if \, w_b + w_i/2 \le d_x$

where $a = \dfrac{4}{(w_b+w_i)(2w_b+w_i)}, b = \dfrac{4}{w_b(2w_b+w_i)}$

$D_b(x, y)$ 的架構可用以下 pseudo code 描述

```
bellShapeFunc(module, b)
{
    mW = module.width();
    mH = module.height();

    aX = 4 / ((binW + mW) * (2 * binW + mW));
    bX = 4 / (binW * (2 * binW + mW));
    aY = 4 / ((binH + mH) * (2 * binH + mH));
    bY = 4 / (binH * (2 * binH + mH));

    a = binIdx % binCut;
    b = binIdx / binCut;
    c = module.area() / binArea;
    // c: normalization factor so that the total potential
    // of a block equals its area.

    dX = oldX - ((a + 0.5) * binW + _placement.boundryLeft());
    ABSdX = abs(dX);
    dY = oldY - ((b + 0.5) * binH + _placement.boundryBottom());
    ABSdY = abs(dY);

    thetaX = thetaByConstrs(ABSdX, mW, binW, aX, bX);
    thetaY = thetaByConstrs(ABSdY, mH, binH, aY, bY);
    return c * thetaX * thetaY;
}
```

$\Theta_x(b,i)$可以用以下 pseudo code 描述

```
thetaByConstrs(ABSdX, mW, binW, aX, bX)
{
    if (ABSdX <= mW * 0.5 + binW * 0.5)
        return 1 - aX * (ABSdX^2);
    else if (ABSdX <= mW * 0.5 + binW)
        return bX * (ABSdX - binW - 0.5 * mW)^2;
    else
        return 0;
}
```

$\Theta_x(b,i)$的 gradient 可以用以下 pseudo code 描述

```
thetaGradByConstrs(ABSdX, mW, binW, aX, bX, dX, thetaY, c)
{
    signX = dX's sign;
    if (ABSdX <= mW * 0.5 + binW * 0.5)
        return c * (-2 * aX * signX * ABSdX) * thetaY;
    else if (ABSdX <= mW * 0.5 + binW)
        return c * 2 * bX * signX * (ABSdX - (binW + 0.5 * mW)) * thetaY;
    else
        return 0;
}
```

reference:

1. Teacher's slides unit6
2. NTUplace3's intro slides

C. Try your best to enhance your solution quality. What tricks did you do to enhance your solution quality?

我覺得這次作業的實作上，大家會差不多，頂多是評估 wirelength 的 function 從 log-sum-exponential 換成 weighted average 可以讓線長估的更趨近 HPWL。所以比較難從實作上去優化（如果 runtime 不算在優化範圍內的話)因此優化重點變成是找到好的參數，包括 gamma, stepsize, epoch, numIter, lambda 的初始值和每次要 increase 的量等等。

在我寫好一份確定為正確的版本後，給了一組 hyperparameter
- numIter = 50;
- no.setStepSizeBound(10000);
- EPOCH = 2;
- ef.increaseLambda(1000);
- gamma = 10;

結果如下

testcase	Wirelength	Runtime
Public1	324193780	20.86
Public2	13014416	26.21
Public3	2644255425	91.96

和我最後的結果比較可以發現真的差很多（尤其是 public1 & 3)，它是用以下參數跑出來的
- numIter = (epoch == 0) ? 100 : 70;
- no.setStepSizeBound((bTop - bBottom) * 2);
- EPOCH = 3;
- ef.increaseLambda(8000);
- gamma = chipH / 700;

testcase	Wirelength	Runtime
Public1	71741249	37.43
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D. Please compare your results with the previous top 5 students' results and show your advantage in solution quality. Are your results better than theirs?

➢ **If so, please express your advantages to beat them.**

我的 public1 和 public3 算是有還可以的表現，都有贏過當年第五名。大概是花很多時間找參數，而且晶片比較大，因此就算 LSE 需要較大的 gamma，估出來的線長也不會那麼不准。

➢ **If not, it's fine. If your solution quality is inferior, what do you think that you could do to improve the result in the future?**
public2 遠遠落後前五名，猜測可能是用 WA 估線長才能做到好的表現，因為我發現 public2 的晶片比較小，HPWL 特別容易受 gamma 大小影響，越小的 gamma 越能減少 HPWL，但 LSE 受限於 numerical issue 無法估計很準確的 HPWL，因此十分可惜的沒能盡到當年前五的行列。也許之後有時間可以實作 WA 來比較結果是否如果所猜測會比較好!

➢ **If not, it's fine. If your solution quality is inferior, what do you think that you could do to improve the result in the future?**
public2 遠遠落後前五名，猜測可能是用 WA 估線長才能做到好的表