DESIGN, AUTOMATION & TEST IN EUROPE
01 – 05 February 2021 · virtual conference
The European Event for Electronic System Design & Test

A GPU-enabled Level Set Method for Mask Optimization

Ziyang Yu, Guojin Chen, Yuzhe Ma, Bei Yu

香港中文大學
The Chinese University of Hong Kong

A GPU-enabled Level Set Method for Mask Optimization

Background & Motivation

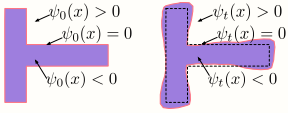
- Optical proximity correction (OPC): Adjusting the photomask to compensate for distortion of printed image in lithography process.
- Pixel based inverse lithography technique (ILT): modifies the pixel-wise mask inversely according to the printed image.
- Mask quality using pixel based ILT could be further improved in pattern fidelity and robustness aspects. The convergence could be unstable in previous work.
- The time-consuming lithosimulation process in mask optimization has space to be accelerated.

Our solution

- Modifying pixel based ILT with levelset method.
- Proposing novel process variation based cost function.
- Developing effective conjugate gradient method.
- Adopting GPU to speed up the optimization process.

Levelset based ILT

- Levelset method



- Cost functions:

$$L_{nom}(\mathbf{M}) = \|\mathbf{R} - \mathbf{R}^*\|_F^2$$

$$L_{pvb}(\mathbf{M}) = \|\mathbf{R}_{in}(\mathbf{M}) - \mathbf{R}^*\|^2 + \|\mathbf{R}_{out}(\mathbf{M}) - \mathbf{R}^*\|^2$$

$$L = L_{nom}(\mathbf{M}) + w_{pvb} L_{pvb}(\mathbf{M})$$

$\mathbf{R}$: printed pattern. $\mathbf{R}^*$: target pattern

$\mathbf{R}_{in}$ / $\mathbf{R}_{out}$: innermost and outermost printed pattern.

- Conjugate gradient method:

$$\mathbf{v}_i = \begin{cases} -G(\mathbf{M})|\nabla\psi_0|, & \text{if } i = 0, \\ -G(\mathbf{M})|\nabla\psi_i| + \lambda_i \mathbf{v}_{i-1}, & \text{if } i > 0, \end{cases}$$

- GPU-enabled acceleration:

$$\mathbf{M} \otimes \mathbf{H} = \sum_{k=1}^{K} \mu_k \cdot (\mathbf{M} \otimes \mathbf{h}_k) = \mathbf{M} \otimes \sum_{k=1}^{K} \mu_k \cdot \mathbf{h}_k$$

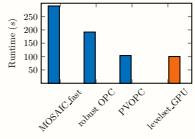
Result

- : Contest score evaluation:

$$\mathbf{Score} = T + 4 \times S_{PVBand} + 5000 \times N_{EPE} + 10000 \times N_{Viol}$$

Case	MOSAIC		robust OPC	PVOPC	Ours
	Fast	Exact			
B1	263246	274267	265150	243240	270895
B2	238812	214493	213878	210826	207977
B3	624101	600955	677256	561367	598994
B4	118298	115161	133371	108030	119508
B5	255327	237363	267713	267342	231116
B6	209238	204224	248625	220414	209881
B7	185475	186761	204495	207982	180288
B8	100186	100031	103691	91541	96095
B9	291646	268138	306667	282907	258466
B10	75703	73276	74205	71425	75140
Avg.	236203	227467	249505	226507	**224836**

- Runtime comparison:



- convergence visualization: