Convergence of Iterated Classification

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Iterated Classification

Training
Ground-truth images
Training images

Testing
Test images

Train — Classify — 1st-stage
Train — Classify — 2nd-stage
Train — Classify — 3rd-stage
. . .
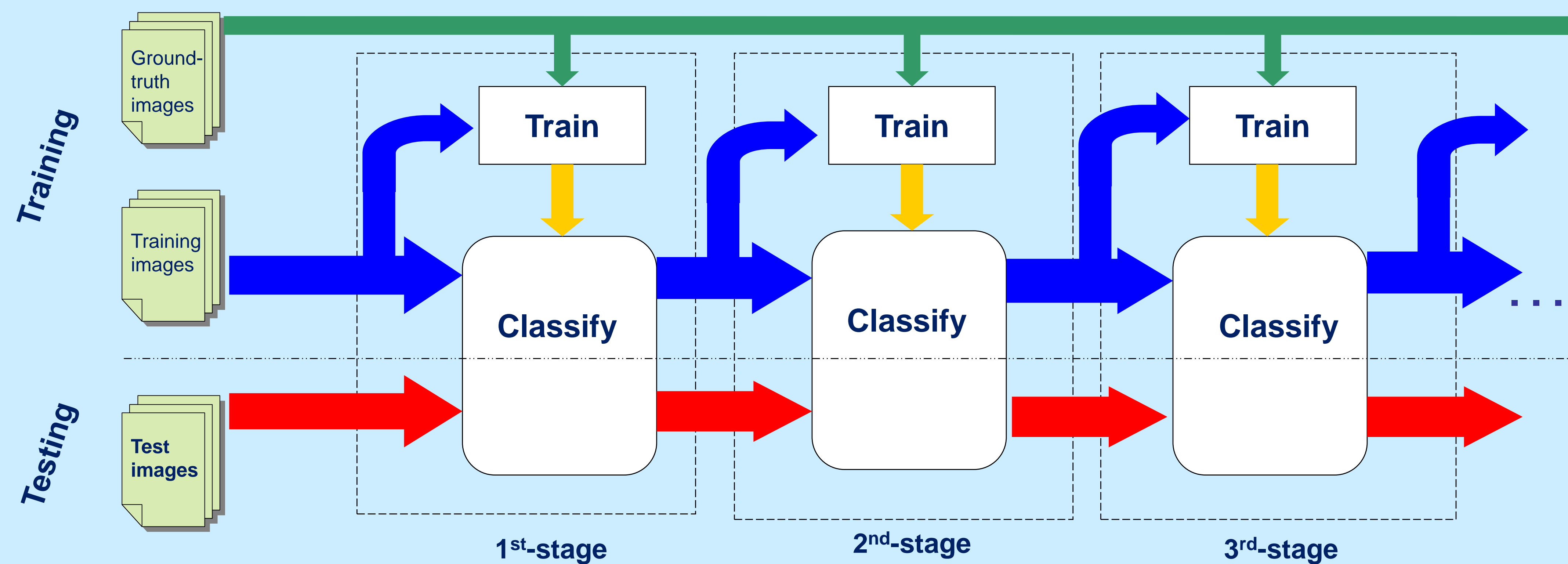
Iterated-classification runs a sequence of classifiers. The same ground-truth is passed to every training phase. Classification results are passed from one classifier to its successor for training and classification. Each classifier is, in general, different from the others.
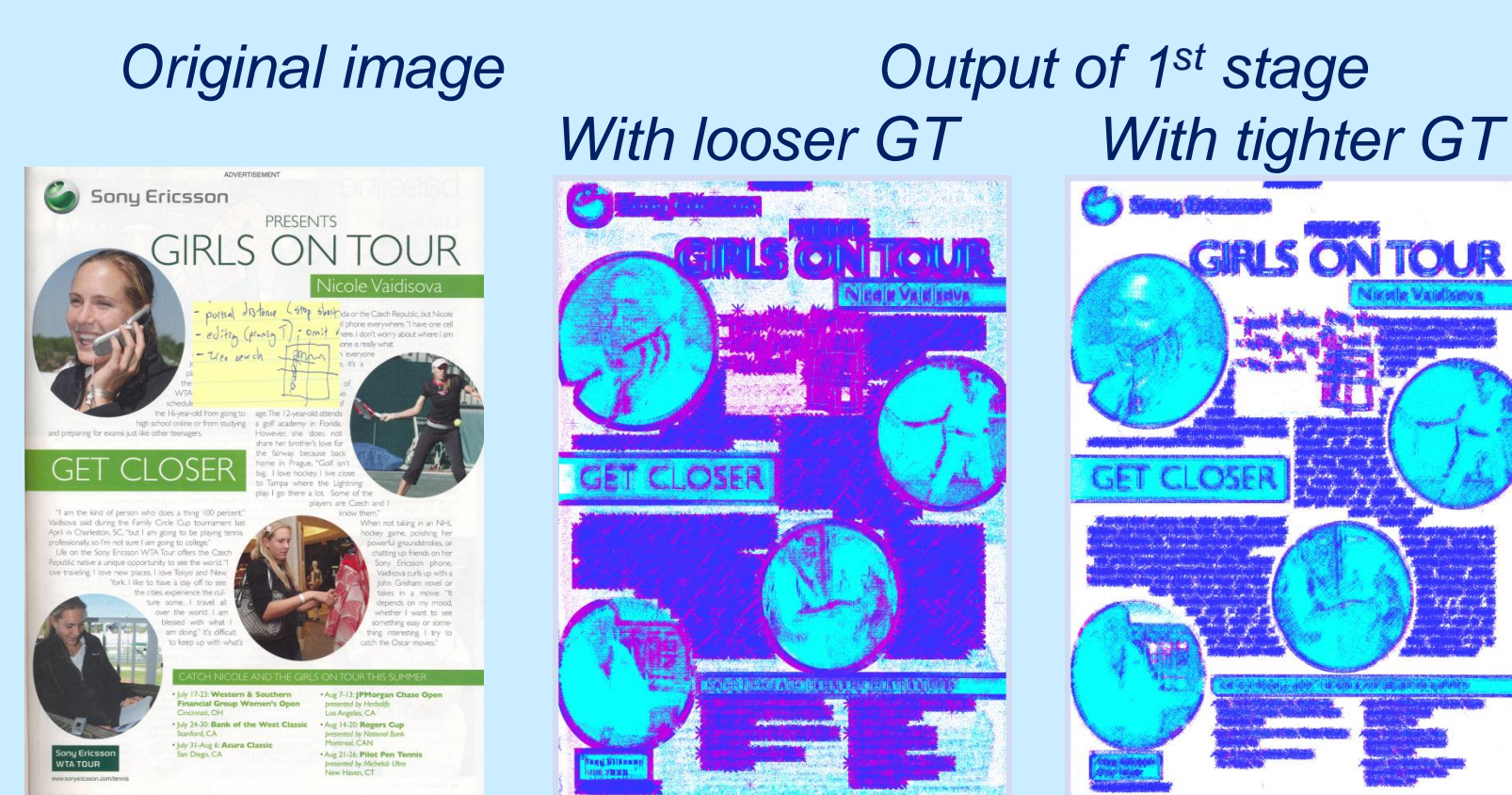
Strengths of Iterated Classification

- Reduces per-pixel error rates significantly
- Enforces local uniformity ("purity") of regions
- Tends to converge region boundaries to the ground-truth (they don't drift)
- Avoids arbitrary restrictions: *e.g. zones need not to be rectangles*
- Requires no manual intervention

Novelty

- Made possible by pixel-accurate classification
- Not the same as Cascading Classifiers
- Not Mathematical Morphology
- Not Markov Random Fields

Proof: Iterated Classifiers Converge to GT

tg | tr | tg tr | tg tr

- We have often observed convergence on real data.
- Proof for a special case: two-class problem, straight-line boundary (details of proof in paper).
- Using one feature that has also worked well on real data.

Task: Pixel-Accurate Segmentation of Document Images

Original image | Output of 1st stage
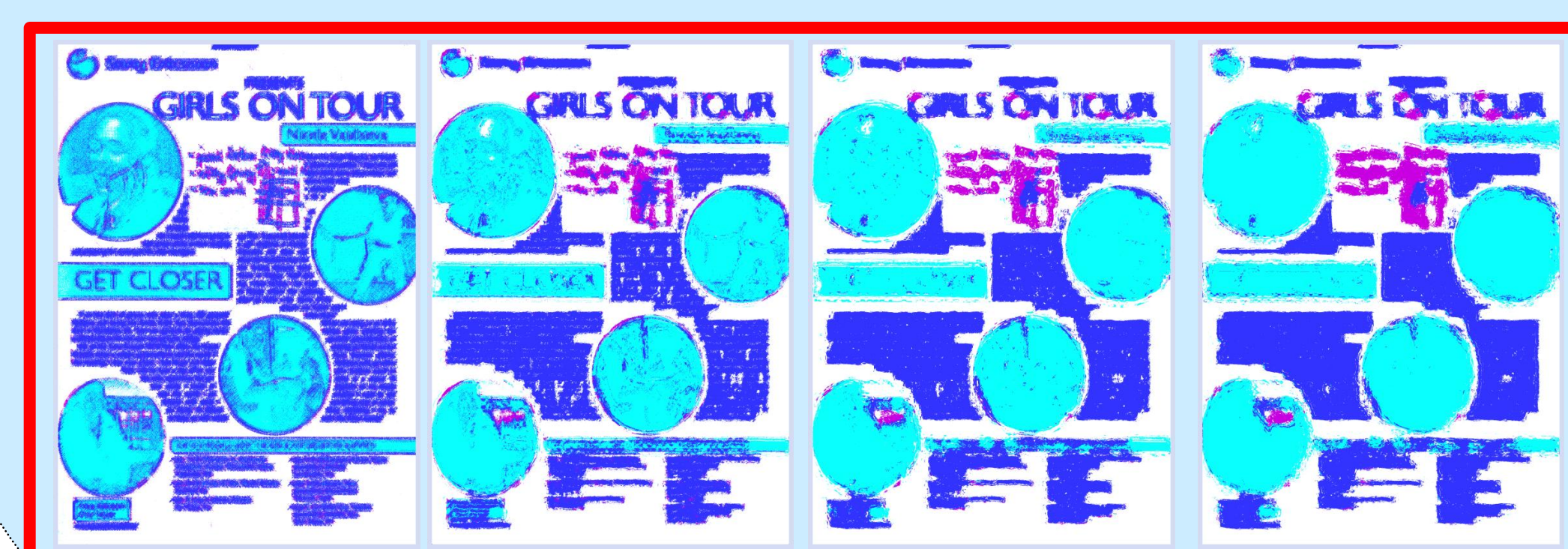With looser GT | With tighter GT

- "Tighter": more careful, detailed and accurate
- Tighter GT reduces the per-pixel errors by **45%**

Color Codes for Content
Blue: Machine Print | White: Blank
Aqua: Photograph | Purple: Handwriting
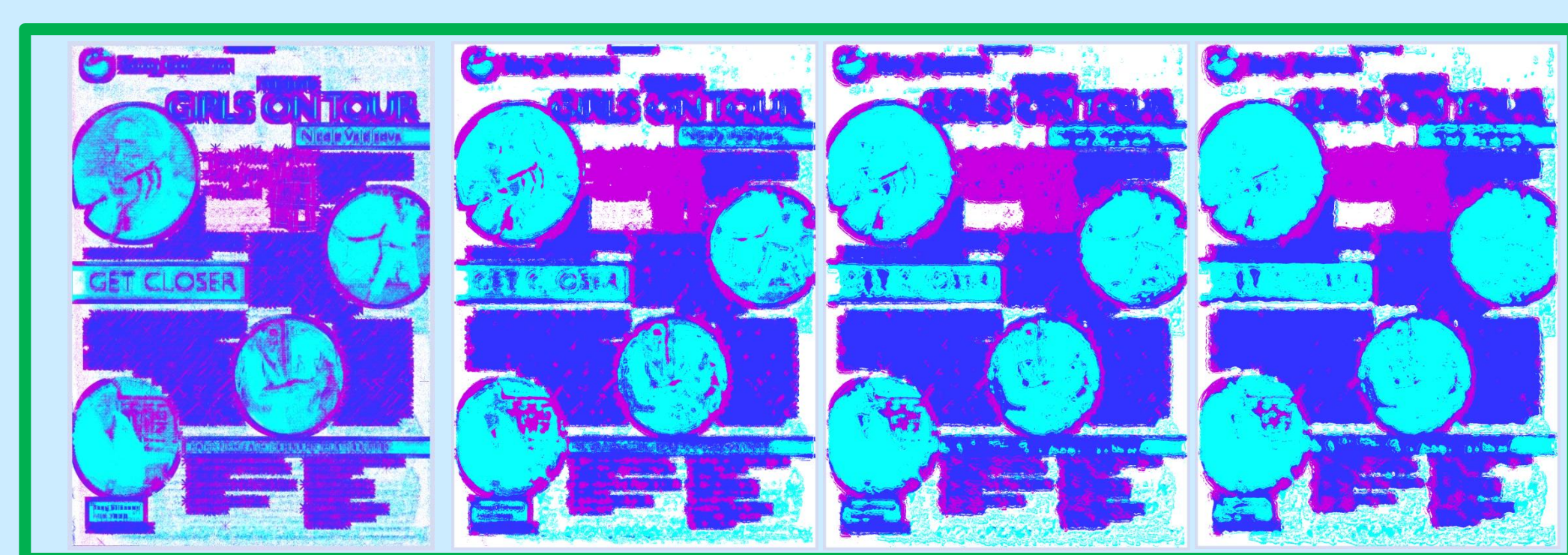
Result for loose ground-truth

- In each stage, a classifier is guided by the GT to correct the errors made by its predecessor
- Note that whether GT is loose or tight, iterated classifiers reduce per-pixel errors and preserve boundaries
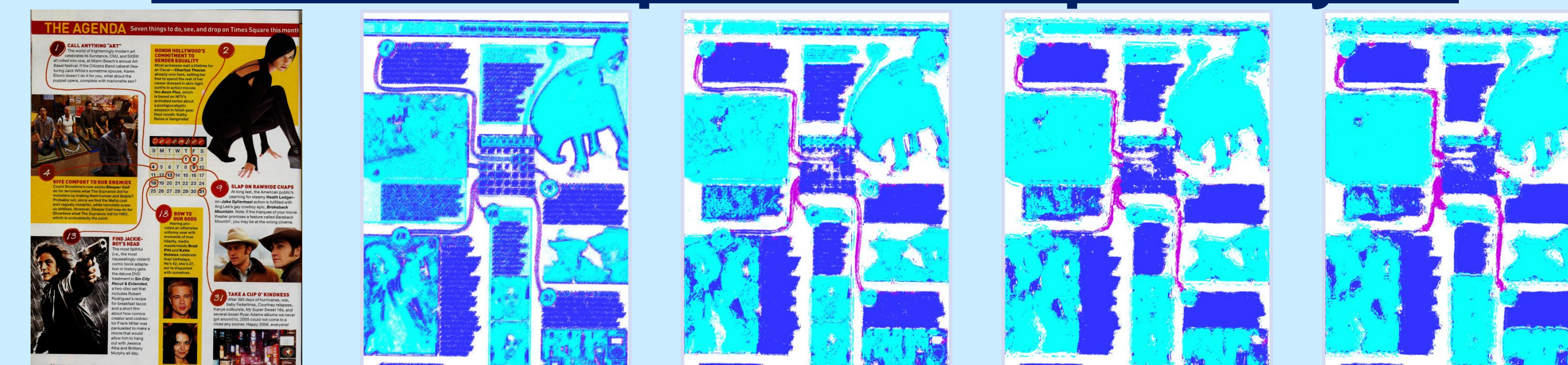- Tight GT allows iterated classifiers to converge more rapidly

Result for tight ground-truth

Future Work

- "Bootstrap" ground-truth: surprisingly, these classifiers often perform **better** than loose GT! Maybe we can use classification results as tight GT.
- Investigate under what conditions iterated classifiers will converge to GT in real problems
- Apply iterated classifiers to image processing problems
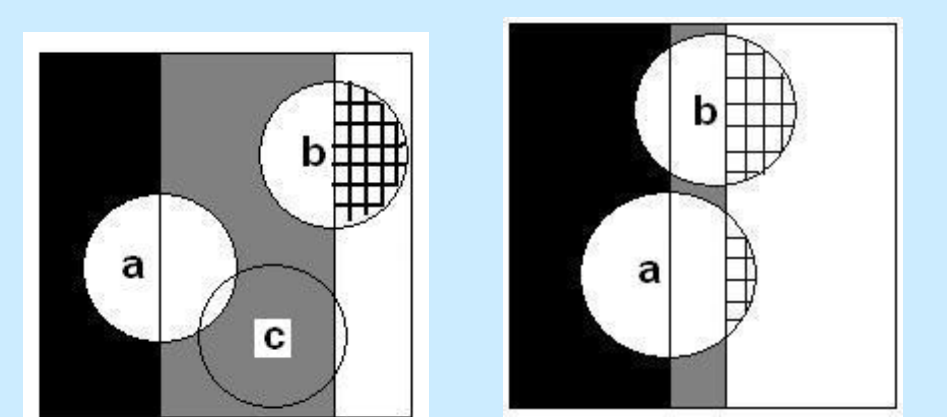
Use Classification to Extract Content Layers

= Photograph (PH) + Machine Print (MP) + Handwriting (HW)
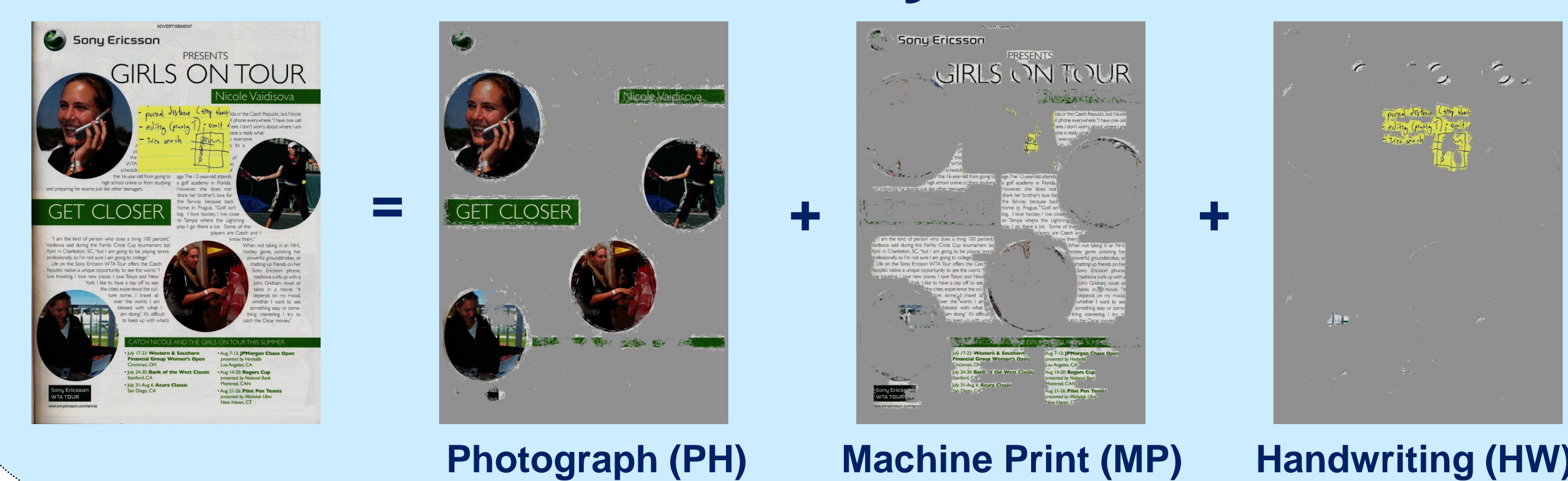
Another Example of a Complex Layout

Note that the small red circles containing numbers are preserved.

Experiments: 24% Drop in Error

Total per-pixel error rate as a function of the stages of classification

Error rate
0.214
0.173
0.165
0.164

1st | 2nd | 3rd | 4th
Stages of classification