



Figure 1: Reconstruction on mixed Type 2 puzzle (864 mixed pieces based on two images from MIT dataset.)

Experiment with noise: To further illustrate the robustness of our method, we conduct experiments with image noise on Type 2 puzzles from MIT dataset. Figure 2 shows the comparison of our approach with Gallagher [3] and Son [6] at different levels of image noise, where we show a large gap in performance of our LP-based puzzle solver. This further illustrates its clear dominance with respect to competing approaches in the presence of noise.

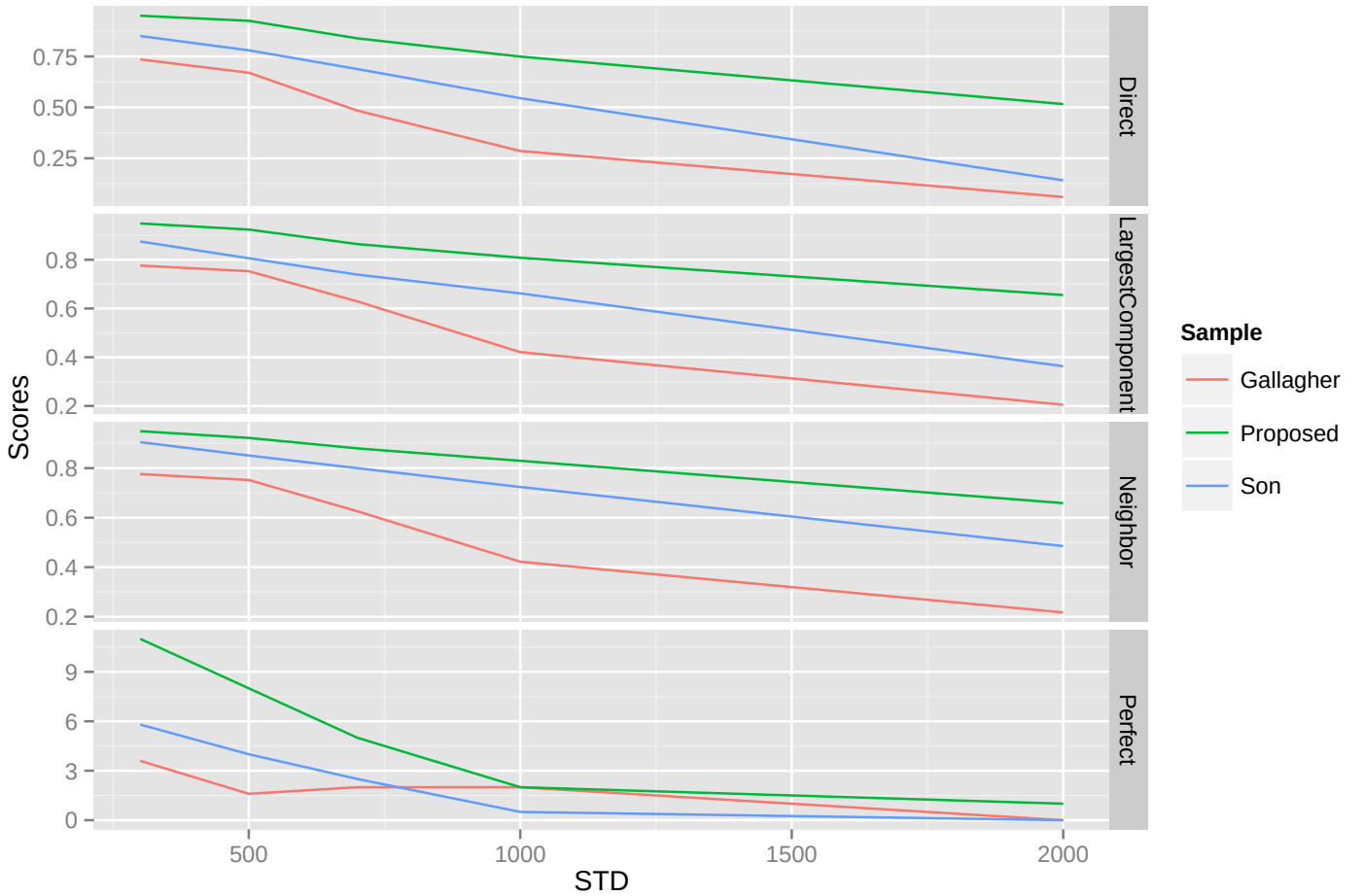


Figure 2: Comparison of our approach vs Gallagher [3] and Son [6] with different amounts of image noise. The X axis shows the standard deviation of the Gaussian noise added to the image intensity (intensities range from 0 to 65535). The Y axis shows the scores on the four performance measures. Results are averaged over five runs, and as such the number of perfect images may be non-integer.

Table 1: Partial Reconstruction performance on Type 1 puzzles from the MIT dataset, The number of pieces is $K = 432$ and the size of each piece is $P = 28$ pixels. *The errors reported here do not include pieces that do not belong to the largest connected component found by the algorithm.*

	Direct	Neighbor	Comp.
Initial LP	99.4%	99.7%	99.4%
Successive LPs	99.7%	99.8%	99.7%
Complete Method	95.7%	95.7%	95.8%

Table 2: Reconstruction performance on Type 1 puzzles from the MIT dataset, The number of pieces is $K = 432$ and the size of each piece is $P = 28$ pixels. The errors reported here for Initial LP and Successive LP treat pieces that do not belong to the largest connected component as errors. As intermediate results need not be rectangular, scores are created by sliding the biggest connected component across the ground truth image and finding best matching locations.

	Direct	Neighbor	Comp.	Perfect
Cho <i>et al.</i> [2]	10 %	55%	-	0
Yang <i>et al.</i> [7]	69.2 %	86.2 %	-	-
Pomeranz <i>et al.</i> [4]	94 %	95 %	-	-
Andalo <i>et al.</i> [1]	91.7%	94.3 %	-	-
Gallagher [3]	95.3%	95.1%	95.3%	12
Sholomon <i>et al.</i> [5]	80.6 %	95.2%	-	-
Son <i>et al.</i> [6]	95.6%	95.5%	95.5%	13
Initial LP	95.1%	94.7%	95.1%	13
Successive LPs (constrained)	95.7%	95.5%	95.7%	14
Constrained	95.7%	95.7%	95.7%	14
Free	95.8%	95.6%	95.8%	14
Hybrid	95.7%	95.7%	95.7%	14
Upper Bound [6]	96.7%	96.4%	96.6%	15

Table 3: Reconstruction performance on Type 2 puzzles from the MIT dataset, The number of pieces is $K = 432$. Each piece is a 28 pixel square.

	Direct	Neighbor	Comp.	Perfect
Gallagher [3]	82.2%	90.4%	88.9%	9
Son <i>et al.</i> [6]	94.7%	94.9%	94.6%	12
Constrained	95.6%	95.3%	95.6%	14
Free	95.6%	95.3%	95.6%	14
Hybrid	95.6%	95.3%	95.6%	14

In the following pages, we show the complete comparison results of Type2 puzzle on MIT dataset. Figures 5, 6, 7, 8 and 9 show more visual reconstruction results from our square jigsaw puzzle solver on the dataset of Cho *et al.* [2]. These qualitative results are in addition to the quantitative results in the main paper. We do not include results from previous algorithms, but visual comparison for the Type 1 puzzle can be made versus Cho *et al.* [2] by referring to their supplemental material (<http://people.csail.mit.edu/taegsang/Documents/JigsawSolverSupplemental.pdf>). Also, the Type 1 puzzle results can be compared with Pomeranz *et al.* [4]. The Type 1 and Type 2 puzzle results can be compared with Gallagher [3] by referring to their supplemental material (<http://tinyurl.com/7udcpps>) and Son *et al.* [6].



(a) Ground truth
(1)



(b) Ours, Type 1, 91.4%
([3] 90.1%, [6] 90.7%)



(c) Ours, Type 2, 88.2%
([3] 76.2%, [6] 89.1%)



(a) Ground truth
(2)



(b) Ours, Type 1, 83.4%
([3] 83.6%, [6] 84.3%)



(c) Ours, Type 2, 83.4%
([3] 81.0%, [6] 83.6%)



(a) Ground truth
(3)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 96.8%
([3] 100%, [6] 100%)



(a) Ground truth
(4)



(b) Ours, Type 1, 64.4%
([3] 64.6%, [6] 64.1%)



(c) Ours, Type 2, 66.2%
([3] 57.6%, [6] 63.9%)

Figure 3: Reconstructions of 432 pieces (1)-(4) without prior knowledge (dimension of the puzzle nor anchor points). The size of patches is 28 28 pixels. Left: original image, Middle: results of solving the Type 1 puzzle (Orientation of each piece is known and position unknown), Right: results of solving the Type 2 puzzle (Both orientation and position of each piece are unknown). The performance(%) is Direct Comparison.



(a) Ground truth
(5)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)



(a) Ground truth
(6)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)



(a) Ground truth
(7)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 79.2%, [6] 96.3%)



(a) Ground truth
(8)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)

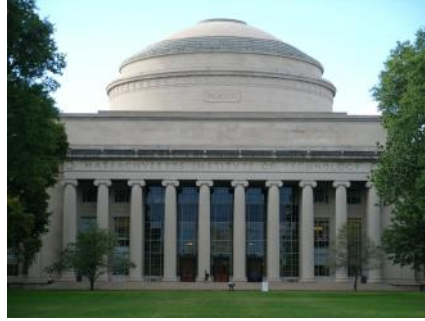


(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)

Figure 4: Reconstructions of 432 pieces (5)-(8) without prior knowledge (dimension of the puzzle nor anchor points). The size of patches is 28 28 pixels. Left: original image, Middle: results of solving the Type 1 puzzle (Orientation of each piece is known and position unknown), Right: results of solving the Type 2 puzzle (Both orientation and position of each piece are unknown). The performance(%) is Direct Comparison.



(a) Ground truth
(9)



(b) Ours, Type 1, 100%
([3] 97.9%, [6] 98.6%)



(c) Ours, Type 2, 100%
([3] 81.9%, [6] 98.6%)



(a) Ground truth
(10)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)



(a) Ground truth
(11)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 94.2%, [6] 100%)



(a) Ground truth
(12)



(b) Ours, Type 1, 91.0%
([3] 85.9%, [6] 88.9%)



(c) Ours, Type 2, 90.1%
([3] 2.6%, [6] 88.2%)

Figure 5: Reconstructions of 432 pieces (9)-(12) without prior knowledge (dimension of the puzzle nor anchor points). The size of patches is 28 28 pixels. Left: original image, Middle: results of solving the Type 1 puzzle (Orientation of each piece is known and position unknown), Right: results of solving the Type 2 puzzle (Both orientation and position of each piece are unknown). The performance(%) is Direct Comparison.



(a) Ground truth
(13)



(b) Ours, Type 1, 90.1%
([3] 88.9%, [6] 88.9%)



(c) Ours, Type 2, 89.4%
([3] 85.9%, [6] 89.6%)



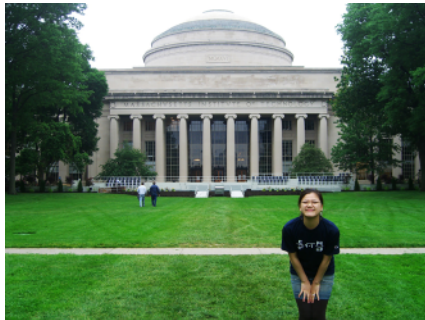
(a) Ground truth
(14)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)



(a) Ground truth
(15)



(b) Ours, Type 1, 96.8%
([3] 96.1%, [6] 96.3%)



(c) Ours, Type 2, 96.1%
([3] 0.0%, [6] 84.3%)



(a) Ground truth
(16)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)

Figure 6: Reconstructions of 432 pieces (13)-(16) without prior knowledge (dimension of the puzzle nor anchor points). The size of patches is 28 28 pixels. Left: original image, Middle: results of solving the Type 1 puzzle (Orientation of each piece is known and position unknown), Right: results of solving the Type 2 puzzle (Both orientation and position of each piece are unknown). The performance(%) is Direct Comparison.



(a) Ground truth
(17)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)



(a) Ground truth
(18)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)



(a) Ground truth
(19)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)



(a) Ground truth
(20)



(b) Ours, Type 1, 100%
([3] 100%, [6] 100%)



(c) Ours, Type 2, 100%
([3] 100%, [6] 100%)

Figure 7: Reconstructions of 432 pieces (17)-(20) without prior knowledge (dimension of the puzzle nor anchor points). The size of patches is 28 28 pixels. Left: original image, Middle: results of solving the Type 1 puzzle (Orientation of each piece is known and position unknown), Right: results of solving the Type 2 puzzle (Both orientation and position of each piece are unknown). The performance(%) is Direct Comparison.

References

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