

Visual Sudoku Puzzle Classification: A Suite of Collective Neuro-Symbolic Tasks



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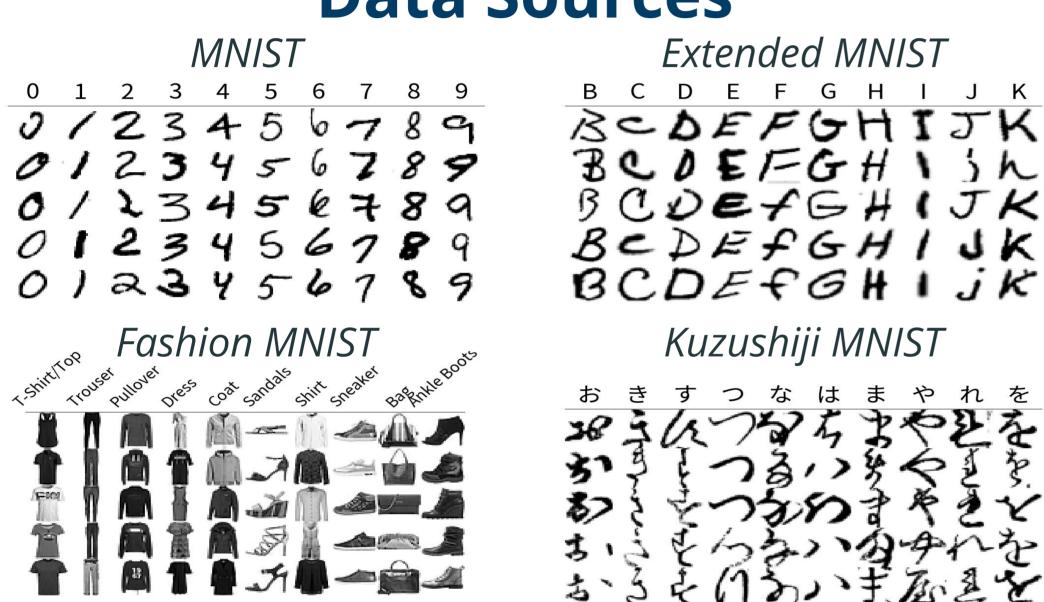
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Goal

Create a suite of tasks that:

- require neural perception and symbolic reasoning
- provide multiple levels of challenge
- can be used in low and noisy data settings
- are easily understood both inside and outside of the NeSy community
- provide utility to the NeSy community

Data Sources



Tasks

Basic

Labels chosen from a single data source, puzzles corrupted for negative examples (red).

| Correct | _ | Incor | rrect | |
|------------------------------|-----------|----------------------|---------------|----------|
| 1023 23/0 320/ 0132 | 032030120 | DECD EDBC CBDE | | うないとうかける |
| MNIST | MNIST | EMNIST-ML | FMNIST | KMNIST |

Random Label Per Split

Allow labels from multiple data sources, labels randomly chosen for each split.

| R73d d312 2dR3 3Rd7 | 60年20621621621 | 1800 001 WO71 WOOW | 1005 005 005 005 005 | 4619 1984 1986 |
|------------------------------|----------------|-----------------------------|----------------------------------|----------------------|
| Split 1 | Split 2 | Snlit 3 | Split 4 | Split 5 |

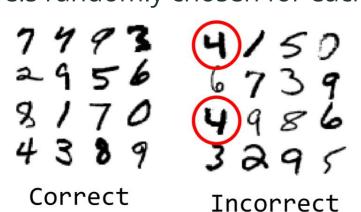
Random Label Per Puzzle

Allow labels from multiple data sources, labels randomly chosen for each puzzle.

| d WC ~ ~ C W d W and C c d Jun | APAGE PAGE | ●マューは 一番 | 人となるとと | 9 V N K X N V 9 N 4 X V V X 5 N |
|---|---------------|--|---------|--|
| Split 1 | Split 1 | Split 1 | Split 1 | Split 1 |

Random Label Per Cell

Allow labels from multiple data sources, labels randomly chosen for each cell.



Transfer

Use labels from a single data source, train ets. an

| id test receive d | |
|---------------------|------------------------------|
| 1823 3218 3381 8132 | DLEB BBCD EDBC CBDE |
| Train | Test |

Puzzle Classification

Visual Sudoku

| 0 | 4 | Z | 3 | 5 | 6 | 8 | 7 | 1 |
|---|---|---|----|---|---|---|---|---|
| 5 | 7 | 6 | 8 | 0 | ١ | 4 | 2 | 3 |
| 8 | 3 | 1 | 4 | 2 | 7 | 6 | 0 | 5 |
| | | | 5 | | | | | |
| 6 | 8 | 5 | 0 | 7 | 2 | / | 3 | 4 |
| 3 | 0 | 7 | } | H | 8 | 2 | 5 | 6 |
| 2 | 5 | 0 | 7 | / | 4 | 3 | 6 | 8 |
| Ч | 6 | 3 | 2 | 8 | 5 | 7 | (| 0 |
| 7 | 1 | 8 | 72 | 3 | 0 | 0 | 4 | a |

Results

SOTA Theoretical IID Best

| Data Source | Model | Image Accuracy | Expected 4x4 Accuracy | Expected 9x9 Accuracy |
|----------------------------|------------------|-------------------|--------------------------|--------------------------|
| MNIST | CNN Ensemble [9] | 99.91% | 98.57% | 98.57% |
| EMNIST-Merged ⁴ | WaveMix [18] | 91.59% | 24.52% | 00.08% |
| FMNIST | DARTS [19] | 96.91% | 60.52% | 07.87% |
| KMNIST | SpinalNet [20] | 99.15% | 87.23% | 50.09% |

Basic, 4x4, Full Data, No Digit Labels

| Data Source | Baseline-Digit | Baseline-Visual | NeuPSL [1] |
|------------------|-----------------|-----------------|-----------------|
| MNIST | 0.71 ± 0.04 | 0.51 ± 0.02 | 0.88 ± 0.02 |
| EMNIST-ML | 0.69 ± 0.05 | 0.50 ± 0.01 | 0.79 ± 0.09 |
| FMNIST | 0.70 ± 0.04 | 0.50 ± 0.03 | 0.74 ± 0.04 |
| KMNIST | 0.71 ± 0.03 | 0.50 ± 0.02 | 0.65 ± 0.12 |

[1] C. Pryor*, C. Dickens*, E. Augustine, A. Albalak, W.Y. Wang, and L. Getoor. NeuPSL: Neural Probabilistic Soft Logic. arXiv. 2022.

Random Label Per Split, 4x4, No Digit Labels

