New CA Classifiers (random colours)

Wolfram Classes of ECAs

In[1]:=
```
CAclasses = {1, 2, 2, 2, 2, 2, 2, 2, 1, 2, 2, 2, 2, 2, 2, 2, 2, 2, 3, 2, 2, 2, 3,
   2, 2, 2, 2, 2, 2, 2, 3, 2, 1, 2, 2, 2, 2, 2, 2, 2, 1, 3, 2, 2, 2, 3, 2, 2, 2,
   2, 2, 2, 2, 2, 4, 2, 2, 2, 2, 2, 3, 2, 2, 2, 1, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2,
   3, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 3, 2, 2, 3, 3, 2, 2, 2, 2, 2, 1, 3, 2, 2, 2,
   3, 3, 2, 2, 3, 3, 3, 2, 2, 4, 2, 2, 2, 2, 2, 2, 2, 2, 2, 3, 3, 3, 2, 4, 2, 3,
   2, 1, 3, 2, 2, 2, 2, 2, 3, 1, 4, 2, 2, 2, 2, 2, 2, 2, 2, 3, 4, 2, 3, 3, 3, 2,
   3, 2, 2, 2, 2, 2, 2, 1, 3, 2, 2, 2, 3, 2, 2, 1, 3, 2, 2, 2, 2, 2, 2, 2, 2, 2,
   2, 2, 2, 3, 3, 2, 2, 2, 2, 2, 2, 2, 2, 1, 4, 2, 3, 2, 2, 2, 2, 2, 2, 2, 2, 2,
   2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 3, 2, 2, 2, 2, 2,
   2, 2, 2, 1, 1, 2, 2, 1, 1, 2, 2, 2, 2, 2, 2, 2, 2, 1, 1, 1, 1, 1, 1, 1};
```

Functions for creating net and random datasets (ECAs, all 4 classes)

In[2]:=
```
RandomRuleC[n_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[n, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame → False]]
netC[W_Integer, H_Integer] := NetInitialize@
  NetChain[{ConvolutionLayer[16, {2, 3}], Ramp, PoolingLayer[{H, W} - {1, 2}],
    FlattenLayer[], LinearLayer[256], SoftmaxLayer[]},
   "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[0, 255]}]]
netTwoCC[W_Integer, H_Integer] := NetInitialize@
  NetChain[<|"conv1" → ConvolutionLayer[16, {2, 3}], "ramp1" → Ramp,
    "conv3" → ConvolutionLayer[16, {2, 3}], "ramp2" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {2, 4}], "flatten" → FlattenLayer[],
    "linear" → 512, "linear2" → 4, "softmax" → SoftmaxLayer[]|>,
   "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
dataC[W_Integer, H_Integer, n_Integer] := Table[
  RandomRuleC[i, W, H] → CAclasses[[i + 1]], {i, RandomChoice[Range[0, 255], n]}]
```

In[6]:=
```
netThreeCC[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"conv1" → ConvolutionLayer[16, {2, 3}],
    "ramp1" → Ramp, "conv2" → ConvolutionLayer[16, {2, 3}],
    "ramp2" → Ramp, "conv3" → ConvolutionLayer[16, {2, 3}], "ramp3" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {4, 8}], "flatten" → FlattenLayer[],
    "linear" → 512, "linear2" → 4, "softmax" → SoftmaxLayer[]|>,
   "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

In[7]:=
```
netThreeCC1024[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"conv1" → ConvolutionLayer[16, {2, 3}],
    "ramp1" → Ramp, "conv2" → ConvolutionLayer[16, {2, 3}],
    "ramp2" → Ramp, "conv3" → ConvolutionLayer[16, {2, 3}], "ramp3" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {4, 8}], "flatten" → FlattenLayer[],
    "linear" → 1024, "linear2" → 4, "softmax" → SoftmaxLayer[]|>,
   "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

In[8]:=
```
netFourCC512[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"conv1" → ConvolutionLayer[32, {2, 3}],
    "ramp1" → Ramp, "conv3" → ConvolutionLayer[32, {2, 3}], "ramp2" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {2, 4}], "flatten" → FlattenLayer[],
    "linear" → 512, "linear2" → 4, "softmax" → SoftmaxLayer[]|>,
   "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

In[9]:=
```
netFiveCC512[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"conv1" → ConvolutionLayer[32, {2, 3}],
    "bat1" → BatchNormalizationLayer[], "ramp1" → Ramp,
    "conv3" → ConvolutionLayer[32, {2, 3}],
    "bat2" → BatchNormalizationLayer[], "ramp2" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {2, 4}], "flatten" → FlattenLayer[],
    "linear" → 512, "linear2" → 4, "softmax" → SoftmaxLayer[]|>,
   "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

In[10]:=
```
netSixCC512drop[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"drop1" → DropoutLayer[0.2], "conv1" →
     ConvolutionLayer[32, {3, 3}], "bat1" → BatchNormalizationLayer[],
    "ramp1" → Ramp, "conv3" → ConvolutionLayer[32, {3, 3}],
    "bat2" → BatchNormalizationLayer[], "ramp2" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {4, 8}], "flatten" → FlattenLayer[],
    "linear" → 512, "drop2" → DropoutLayer[0.2], "linear2" → 4,
    "softmax" → SoftmaxLayer[]|>, "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

In[11]:=
```
netSevenCC512drop[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"conv1" → ConvolutionLayer[24, {3, 3}],
    "bat1" → BatchNormalizationLayer[], "ramp1" → Ramp,
    "conv3" → ConvolutionLayer[24, {3, 3}],
    "bat2" → BatchNormalizationLayer[], "ramp2" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {4, 8}], "flatten" → FlattenLayer[],
    "linear" → 512, "drop2" → DropoutLayer[0.2], "linear2" → 4,
    "softmax" → SoftmaxLayer[]|>, "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

In[12]:=
```
netEightCC512drop[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"conv1" → ConvolutionLayer[24, {3, 3}],
    "bat1" → BatchNormalizationLayer[], "ramp1" → Ramp,
    "conv2" → ConvolutionLayer[16, {2, 3}], "bat2" → BatchNormalizationLayer[],
    "ramp2" → Ramp, "conv3" → ConvolutionLayer[24, {3, 3}],
    "bat3" → BatchNormalizationLayer[], "ramp3" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {8, 16}], "flatten" → FlattenLayer[],
    "linear" → 1024, "drop2" → DropoutLayer[0.2], "linear2" → 4,
    "softmax" → SoftmaxLayer[]|>, "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

In[13]:=
```
netNineCC512drop[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"conv1" → ConvolutionLayer[24, {3, 3}],
    "bat1" → BatchNormalizationLayer[], "ramp1" → Ramp,
    "conv2" → ConvolutionLayer[24, {3, 3}], "bat2" → BatchNormalizationLayer[],
    "ramp2" → Ramp, "conv3" → ConvolutionLayer[24, {3, 3}],
    "bat3" → BatchNormalizationLayer[], "ramp3" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {12, 12}], "flatten" → FlattenLayer[],
    "linear" → 512, "drop2" → DropoutLayer[0.2], "linear2" → 4,
    "softmax" → SoftmaxLayer[]|>, "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

In[14]:=
```
netTenCC1024drop[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"conv1" → ConvolutionLayer[24, {3, 3}],
    "bat1" → BatchNormalizationLayer[], "ramp1" → Ramp,
    "conv2" → ConvolutionLayer[24, {3, 3}], "bat2" → BatchNormalizationLayer[],
    "ramp2" → Ramp, "conv3" → ConvolutionLayer[24, {3, 3}],
    "bat3" → BatchNormalizationLayer[], "ramp3" → Ramp,
    "conv4" → ConvolutionLayer[24, {3, 3}],
    "bat4" → BatchNormalizationLayer[], "ramp4" → Ramp,
    "pooling" → PoolingLayer[{H, W} - {12, 12}], "flatten" → FlattenLayer[],
    "linear" → 1024, "drop2" → DropoutLayer[0.3], "linear2" → 4,
    "softmax" → SoftmaxLayer[]|>, "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

In[15]:=
```
netElevenCC1024drop[W_Integer, H_Integer] :=
 NetInitialize@NetChain[<|"conv1" → ConvolutionLayer[48, {3, 3}],
    "bat1" → BatchNormalizationLayer[], "ramp1" → Ramp,
    "pooling1" → PoolingLayer[{2, 2}], "conv2" → ConvolutionLayer[24, {3, 3}],
    "bat2" → BatchNormalizationLayer[], "ramp2" → Ramp,
    "pooling2" → PoolingLayer[{2, 2}], "conv3" → ConvolutionLayer[24, {3, 3}],
    "bat3" → BatchNormalizationLayer[], "ramp3" → Ramp,
    "pooling3" → PoolingLayer[{2, 2}], "conv4" → ConvolutionLayer[12, {3, 3}],
    "bat4" → BatchNormalizationLayer[], "ramp4" → Ramp,
    "pooling4" → PoolingLayer[{2, 2}], "flatten" → FlattenLayer[],
    "linear" → 1024, "drop2" → DropoutLayer[0.3], "linear2" → 4,
    "softmax" → SoftmaxLayer[]|>, "Input" → NetEncoder[{"Image", {W, H}}],
   "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

Functions for creating datasets (1D totalistic CAs)

k=3, r=1 totalistic (class 4 only)

In[16]:=
```
gen3TC[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {3, 1}}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
data3T2C[W_Integer, H_Integer, n_Integer] := Table[gen3TC[i, W, H] → 4,
  {i, RandomChoice[{1635, 1815, 2007, 2043, 2049, 1388, 1041}, n]}]
```

k=4, r=1 totalistic (class 4 only, 1 example)

In[18]:=
```
gen4TC[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {4, 1}}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
data4TC[W_Integer, H_Integer, n_Integer] := Table[gen4TC[1 004 600, W, H] → 4, n]
```

k=2, r=2 totalistic (all 4 classes)

In[20]:=
```
gen2r2C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {2, 1}, 2}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
data2r2c4C[W_Integer, H_Integer, n_Integer] :=
 Table[gen2r2C[i, W, H] → 4, {i, RandomChoice[{20, 52}, n]}]
data2r2c3C[W_Integer, H_Integer, n_Integer] :=
 Table[gen2r2C[i, W, H] → 3, {i, RandomChoice[
    {2, 6, 10, 12, 14, 18, 22, 26, 28, 30, 34, 38, 42, 44, 46, 50}, n]}]
data2r2c2C[W_Integer, H_Integer, n_Integer] :=
 Table[gen2r2C[i, W, H] → 2, {i, RandomChoice[{8, 24, 56}, n]}]
data2r2c1C[W_Integer, H_Integer, n_Integer] := Table[gen2r2C[i, W, H] → 1,
  {i, RandomChoice[{0, 4, 16, 32, 36, 40, 48, 54, 58, 60, 62}, n]}]
genData2r2C[W_Integer, H_Integer, n_Integer] := Join[data2r2c4C[W, H, n],
  data2r2c3C[W, H, n], data2r2c2C[W, H, n], data2r2c1C[W, H, n]]
```

k=5, r=1 totalistic (class 4 only)

In[26]:=
```
gen5T4C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {5, 1}}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
data5T4C[n_Integer, W_Integer, H_Integer] :=
 Table[gen5T4C[i, W, H] → 4, {i, RandomChoice[
    {781 130 654, 772 514 435, 1 151 319 452, 309 095 787, 880 862 046, 973 835 714,
     779 446 817, 345 466 505, 535 500 975, 793 363 571, 1 052 373 865, 455 984 785,
     339 227 109, 1 050 973 846, 513 368 817, 91 315 820, 113 925 357}, n]}]
```

k=5, r=1 totalistic (classes 2/3/4)

In[28]:=
```
gen5TC[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {5, 1}, 1}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
data5T4CC[W_Integer, H_Integer, n_Integer] := Table[gen5TC[i, W, H] → 4,
  {i, RandomChoice[{644 218 533, 491 739 943, 6 889 640, 986 144 962, 1 099 816 682,
     988 971 204, 300 829 994, 272 622 024, 304 100 638, 626 595 633}, n]}]
data5T3CC[W_Integer, H_Integer, n_Integer] := Table[gen5TC[i, W, H] → 3,
  {i, RandomChoice[{889 082 395, 541 068 260, 807 907 479, 816 180 062, 650 485 139,
     643 827 745, 753 940 864, 871 525 323, 351 440 311, 83 501 460}, n]}]
data5T2CC[W_Integer, H_Integer, n_Integer] :=
 Table[gen5TC[i, W, H] → 2, {i, RandomChoice[
    {525 735 659, 1 022 330 944, 1 007 796 739, 495 633 437, 1 036 827 943}, n]}]
genData5TCC[W_Integer, H_Integer, n_Integer] :=
 Join[data5T4CC[W, H, n], data5T3CC[W, H, n], data5T2CC[W, H, n]]
```

Generate test datasets

k=2, r=2 non-totalistic

In[33]:=
```
genk2r2C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, 2, 2}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
datak2r2C[W_Integer, H_Integer, n_Integer] :=
 Table[genk2r2C[i, W, H] → i, {i, RandomChoice[Range[0, 4 294 967 295], n]}]
```

k=2, r=3 non-totalistic

In[35]:=
```
genk2r3NT[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, 2, 3}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
datak2r3NT[W_Integer, H_Integer, n_Integer] :=
 Table[genk2r3NT[i, W, H] → i, {i, RandomInteger[2^2^7 - 1, n]}]
```

k=3, r=1 non-totalistic

In[37]:=
```
genk3r1NT[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, 3}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
datak3r1NT[W_Integer, H_Integer, n_Integer] :=
 Table[genk3r1NT[i, W, H] → i, {i, RandomInteger[3^3^3 - 1, n]}]
```

k=3, r=2 totalistic

In[39]:=
```
genk3r2C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {3, 1}, 2}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
datak3r2C[W_Integer, H_Integer, n_Integer] :=
 Table[genk3r2C[i, W, H] → i, {i, RandomChoice[Range[0, 177146], n]}]
```

k=3, r=3 totalistic

In[41]:=
```
genk3r3C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {3, 1}, 3}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
datak3r3C[W_Integer, H_Integer, n_Integer] :=
 Table[genk3r3C[i, W, H] → i, {i, RandomChoice[Range[0, 14348906], n]}]
```

k=4, r=1 non-totalistic

In[43]:=
```
genk4r1NT[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, 4}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
datak4r1NT[W_Integer, H_Integer, n_Integer] :=
 Table[genk4r1NT[i, W, H] → i, {i, RandomInteger[4^4^3 - 1, n]}]
```

k=4, r=1 totalistic

In[45]:=
```
genk4r1C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {4, 1}}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
datak4r1C[W_Integer, H_Integer, n_Integer] :=
 Table[genk4r1C[i, W, H] → i, {i, RandomChoice[Range[0, 1048575], n]}]
```

k=4, r=2 totalistic

In[47]:=
```
genk4r2C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {4, 1}, 2}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
datak4r2C[W_Integer, H_Integer, n_Integer] :=
 Table[genk4r2C[i, W, H] → i, {i, RandomChoice[Range[0, 4294967295], n]}]
```

k=5, r=1 totalistic

In[49]:=
```
gen5T2C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {5, 1}, 1}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
data5T2C[n_Integer, W_Integer, H_Integer] := Table[gen5T2C[i, W, H] → i,
  {i, RandomChoice[Range[0, 1220703125], n]}]
```

k=6, r=1 totalistic

In[51]:=
```
gen6TC[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {6, 1}, 1}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
data6TC[n_Integer, W_Integer, H_Integer] := Table[gen6TC[i, W, H] → i,
  {i, RandomInteger[2821109907455, n]}]
```

k=6, r=2 totalistic

In[53]:=
```
gen6T2C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {6, 1}, 2}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame -> False]]
data6T2C[n_Integer, W_Integer, H_Integer] := Table[gen6T2C[i, W, H] → i,
  {i, RandomInteger[170 581 728 179 578 208 255, n]}]
```

k=7, r=1 totalistic

In[55]:=
```
gen7TC[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {7, 1}, 1}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame → False]]
data7TC[n_Integer, W_Integer, H_Integer] := Table[gen7TC[i, W, H] → i,
  {i, RandomInteger[11 398 895 185 373 142, n]}]
```

k=8, r=1 totalistic

In[57]:=
```
gen8TC[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {8, 1}, 1}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame → False]]
data8TC[n_Integer, W_Integer, H_Integer] := Table[gen8TC[i, W, H] → i,
  {i, RandomInteger[73 786 976 294 838 206 463, n]}]
```

k=8, r=2 totalistic

In[59]:=
```
gen8T2C[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {8, 1}, 2}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[]}, Frame → False]]
data8T2C[n_Integer, W_Integer, H_Integer] := Table[gen8T2C[i, W, H] → i,
  {i, RandomInteger[324 518 553 658 426 726 783 156 020 576 255, n]}]
```

k=9, r=1 totalistic

In[61]:=
```
gen9TC[p_Integer, W_Integer, H_Integer] :=
 Image[ArrayPlot[CellularAutomaton[{p, {9, 1}, 1}, RandomInteger[1, W], H - 1],
   ImageSize → {W, H}, ColorRules → {0 -> RandomColor[], 1 -> RandomColor[],
     3 -> RandomColor[], 4 → RandomColor[], 5 -> RandomColor[],
     6 -> RandomColor[], 7 -> RandomColor[], 8 → RandomColor[]}, Frame → False]]
data9TC[n_Integer, W_Integer, H_Integer] := Table[gen9TC[i, W, H] → i,
  {i, RandomInteger[717 897 987 691 852 588 770 248, n]}]
```

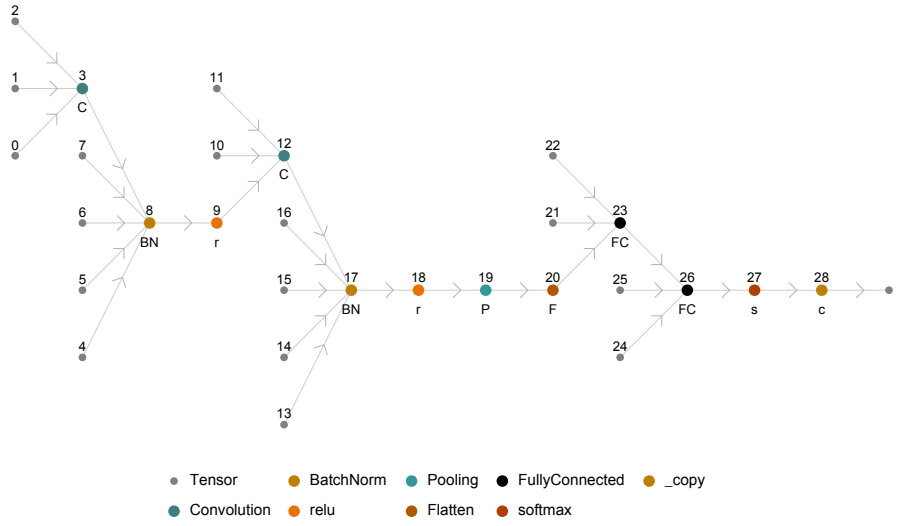
Network XIII - Two convolutions, dropout on linear only, BatchNorm

In[•]:=
```
netECA13 = netSevenCC512drop[128, 128]
```

Out[•]=
NetChain[Input port: image
Output port: class
Number of layers: 12]

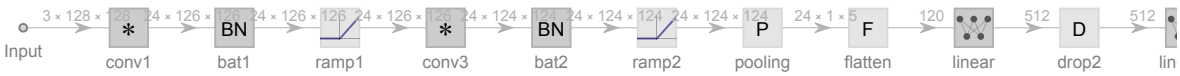
In[•]:=
```
NetInformation[netECA13, "MXNetNodeGraphPlot"]
```

Out[•]=



In[•]:=
```
NetInformation[netECA13, "SummaryGraphic"]
```

Out[•]=



In[•]:=
```
dataECA13 = dataC[128, 128, 8192];
```

In[•]:=
```
dataTotalistic2BigC13 = genData2r2C[128, 128, 1024];
```

In[•]:=
```
dataTotalistic3BigC13 = data3T2C[128, 128, 1024];
```

In[•]:=
```
dataTotalistic4BigC13 = data4TC[128, 128, 1024];
```

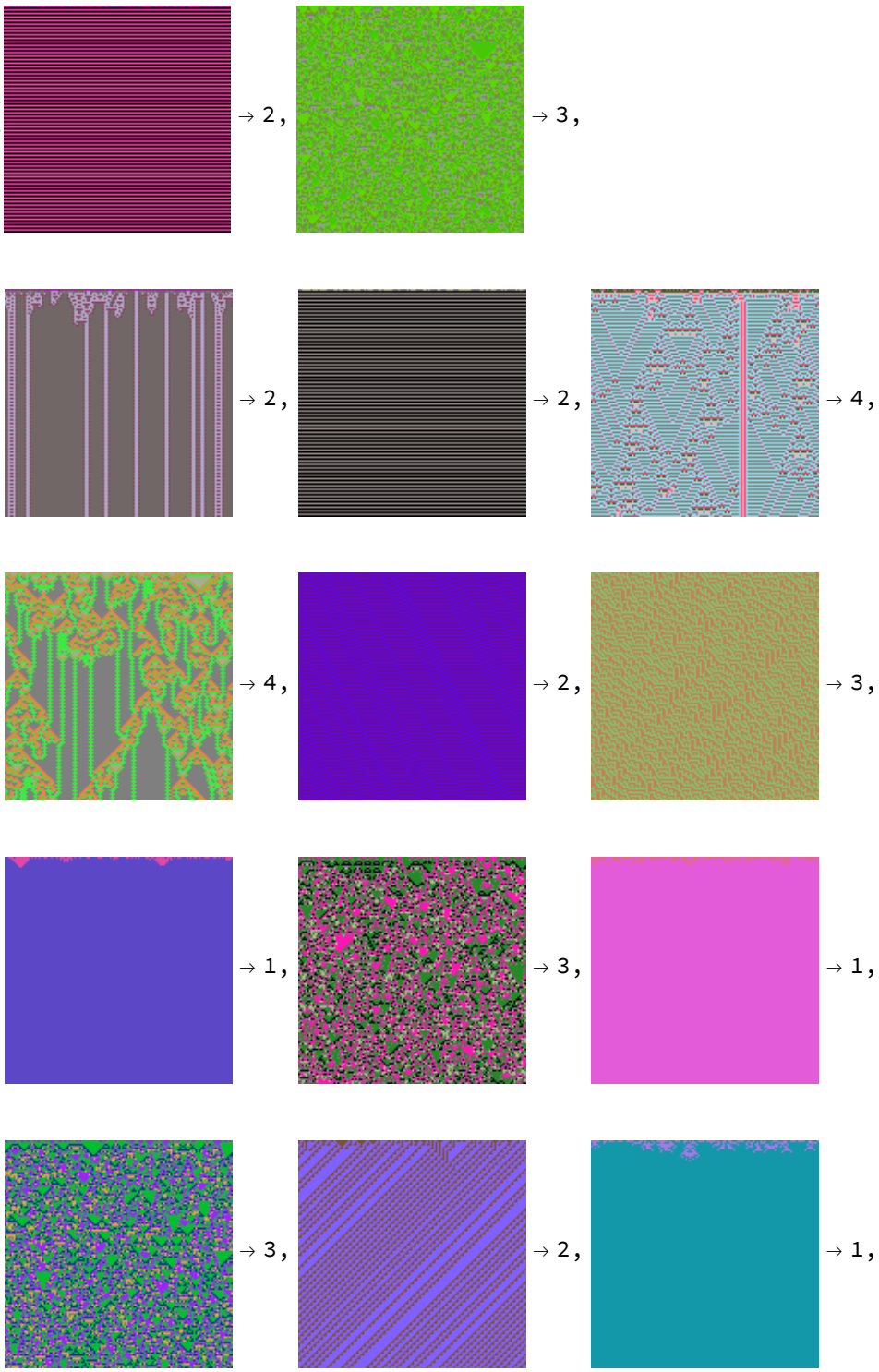
In[•]:=
```
dataTotalistic5BigC13 = genData5TCC[128, 128, 4096];
```

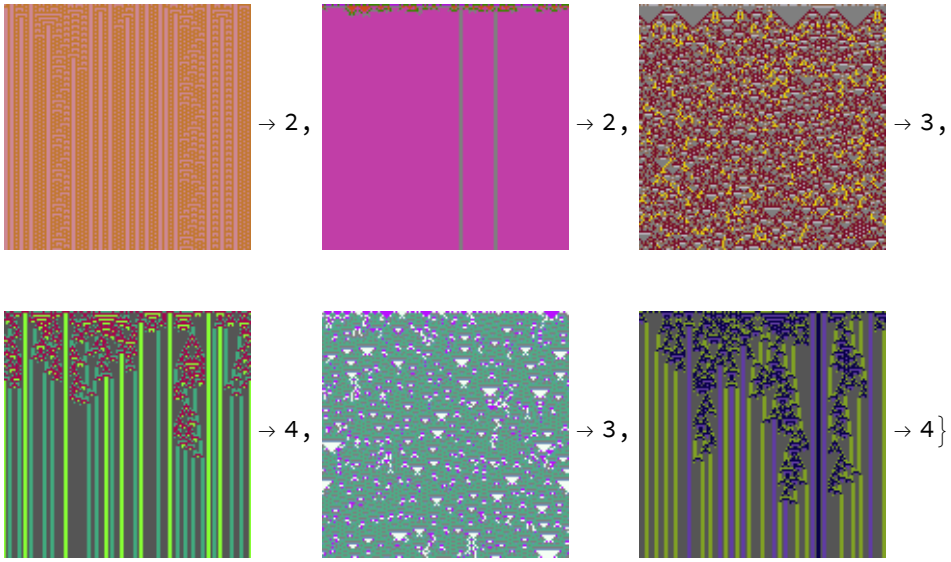
```
In[•]:= fullTrainingBigC13 = Join[dataECA13, dataTotalistic2BigC13,
          dataTotalistic3BigC13, dataTotalistic4BigC13, dataTotalistic5BigC13];
        Length[fullTrainingBigC13]
```

```
Out[•]= 26 624
```

```
In[•]:= RandomSample[fullTrainingBigC13, 20]
```

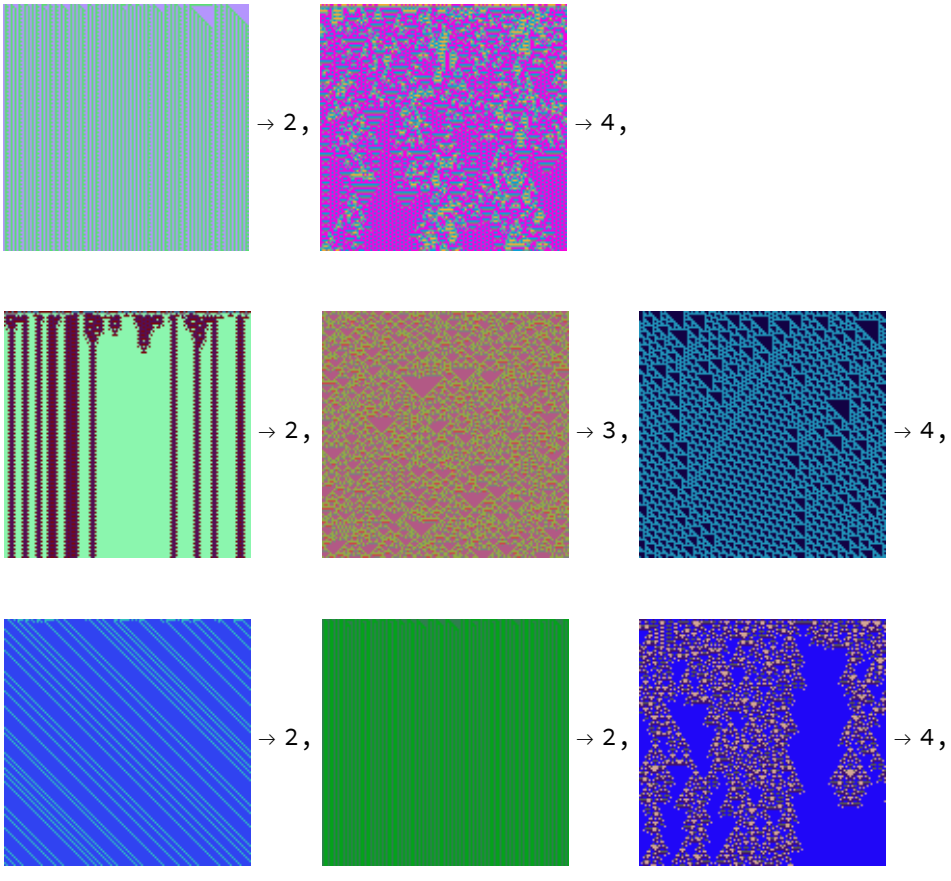
Out[•]=

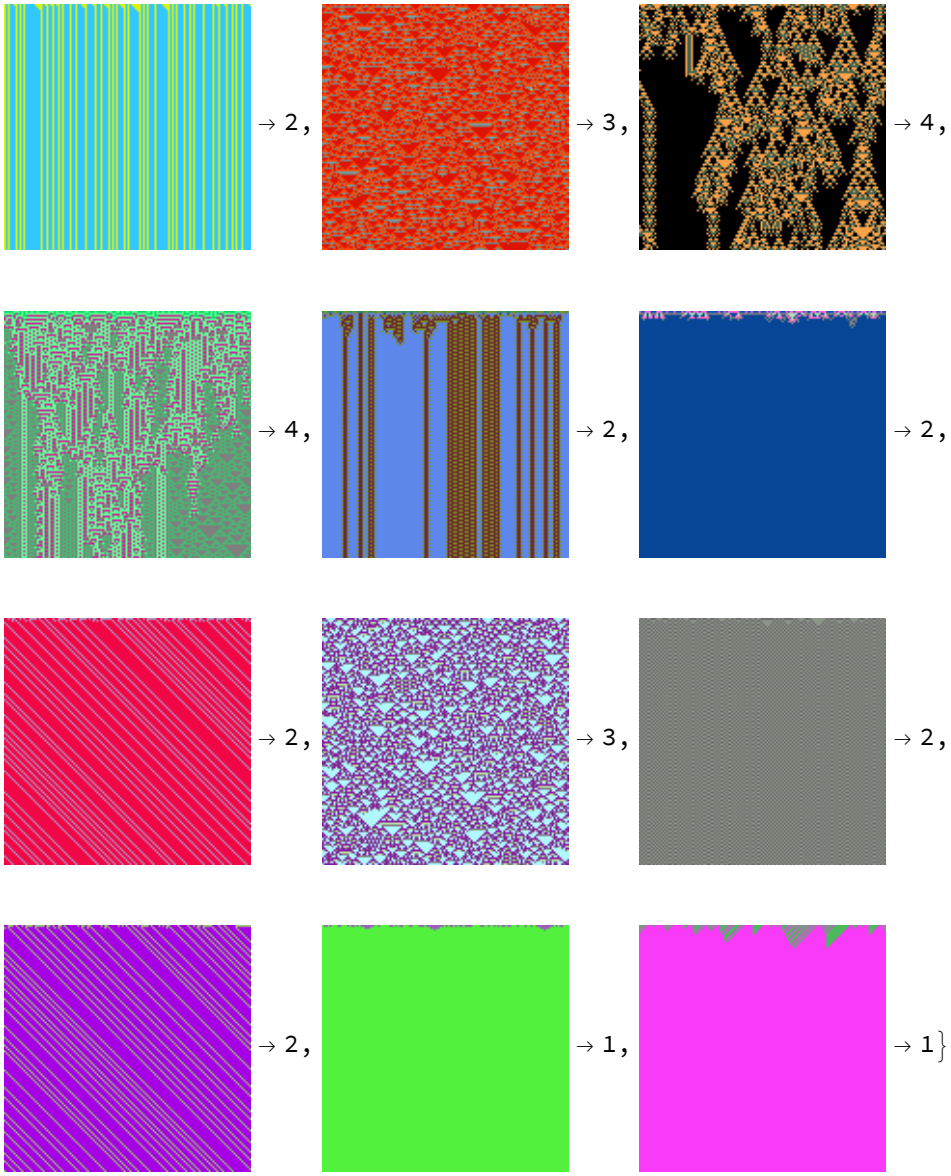




In[ ]:= `RandomSample[fullTrainingBigC13, 20]`

Out[ ]= {





In[•]:= **dir = SetDirectory[NotebookDirectory[]]**

Out[•]= /Users/thorsilver/Downloads/Wolfram notebooks

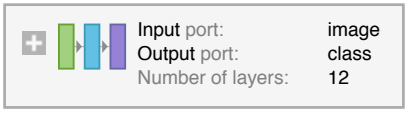
In[•]:= **netECA12 = Import["netECA12-r12.wlnet"]**

Out[•]= NetChain[

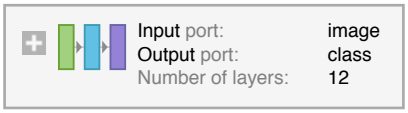
	Input	image array (size: 3 × 120 × 200)
conv1	ConvolutionLayer	array (size: 24 × 118 × 198)
bat1	BatchNormalizationLayer	array (size: 24 × 118 × 198)
ramp1	Ramp	array (size: 24 × 118 × 198)
conv3	ConvolutionLayer	array (size: 24 × 116 × 196)
bat2	BatchNormalizationLayer	array (size: 24 × 116 × 196)
ramp2	Ramp	array (size: 24 × 116 × 196)
pooling	PoolingLayer	array (size: 24 × 1 × 5)
flatten	FlattenLayer	vector (size: 120)
linear	LinearLayer	vector (size: 512)
drop2	DropoutLayer	vector (size: 512)
linear2	LinearLayer	vector (size: 4)
softmax	SoftmaxLayer	vector (size: 4)
	Output	class

]

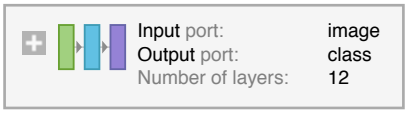
```
In[•]:= netECA13 = NetTrain[netECA13, fullTrainingBigC13,
          MaxTrainingRounds → 20, BatchSize → 256 * 4, TargetDevice → "CPU",
          TrainingProgressCheckpointing → {"Directory", dir}]
```

Out[•]= NetChain[]


```
In[•]:= netECA13 = Import["netECA13-r20.wlnet"]
```

Out[•]= NetChain[]


```
In[•]:= netECA13 = NetTrain[netECA13, fullTrainingBigC13,
          MaxTrainingRounds → 20, BatchSize → 256 * 4, TargetDevice → "CPU",
          TrainingProgressCheckpointing → {"Directory", dir}]
```

Out[•]= NetChain[]

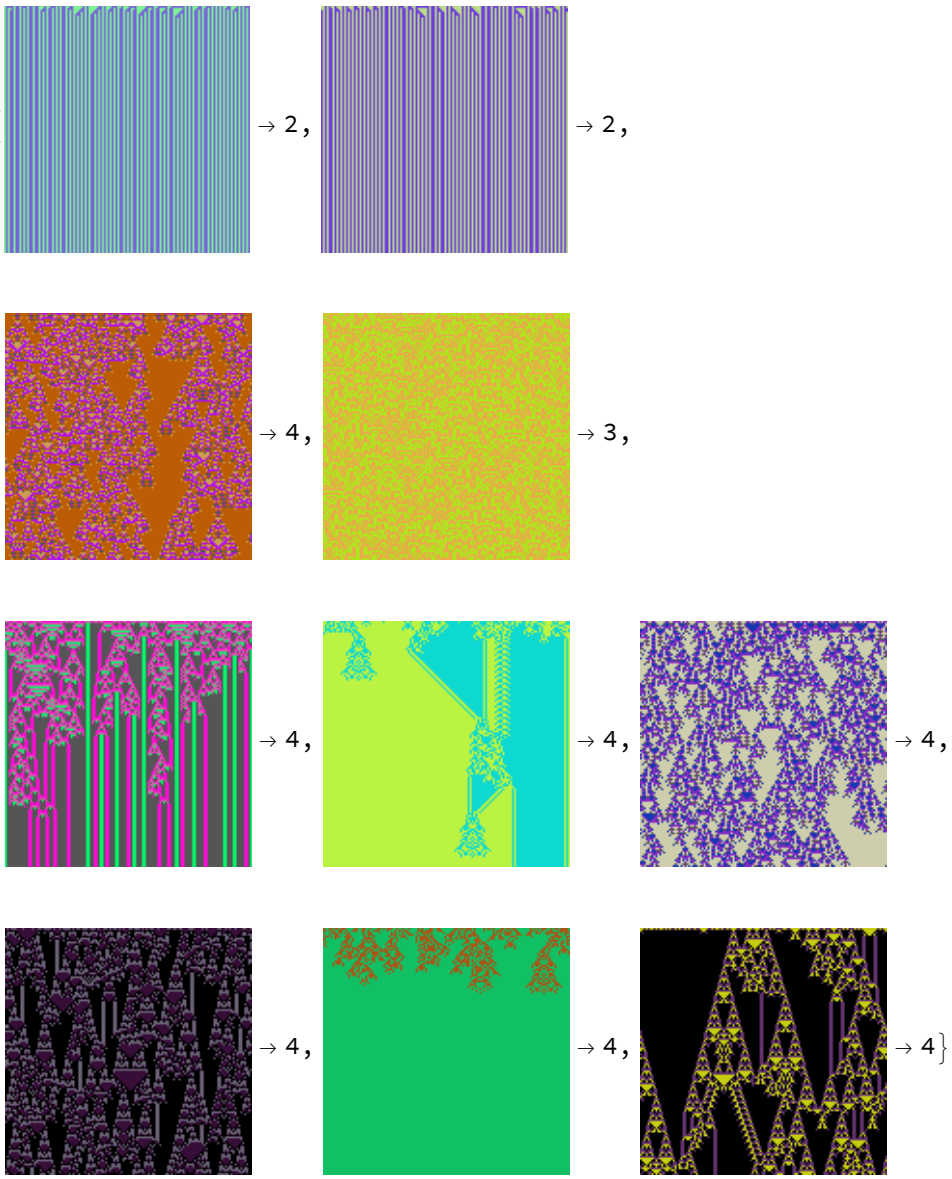
Generate test data for Network XIII

```
In[•]:= testDataECABigC = dataC[128, 128, 1024];
        testData2TBigC = genData2r2C[128, 128, 1024];
        testData3TBigC = data3T2C[128, 128, 1024];
        testData4TBigC = data4TC[128, 128, 1024];
        testData5TBigC = genData5TCC[128, 128, 1024];
        fullTestSetBigC = Join[testDataECABigC,
           testData2TBigC, testData3TBigC, testData4TBigC, testData5TBigC];
        Length[fullTestSetBigC]
```

Out[•]= 10 240

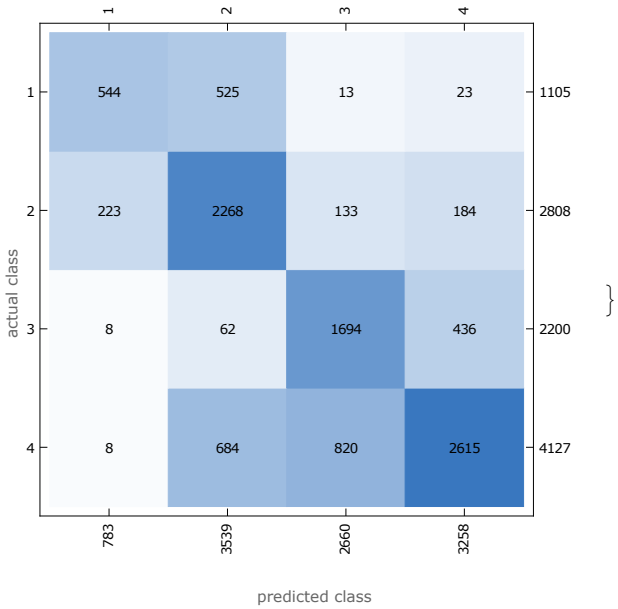
In[•]:= `RandomSample[fullTestSetBigC, 10]`

Out[•]=



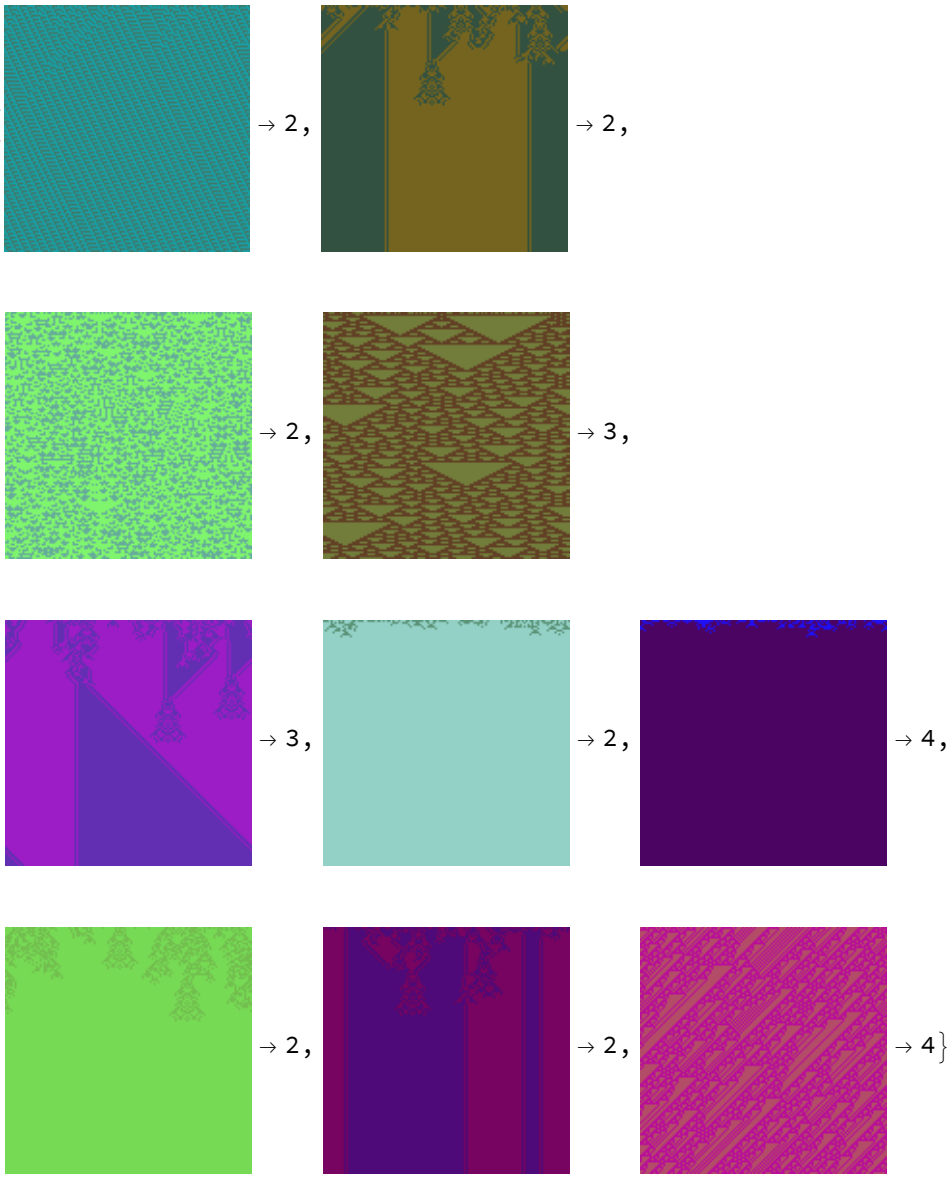
In[]:=
```
NetMeasurements[netECA13, fullTestSetBigC,
 {"Accuracy", "Precision", "ConfusionMatrixPlot"}]
```

Out[]=
```
{0.69541, ⟨|1 → 0.694764, 2 → 0.640859, 3 → 0.636842, 4 → 0.80264|⟩,
```

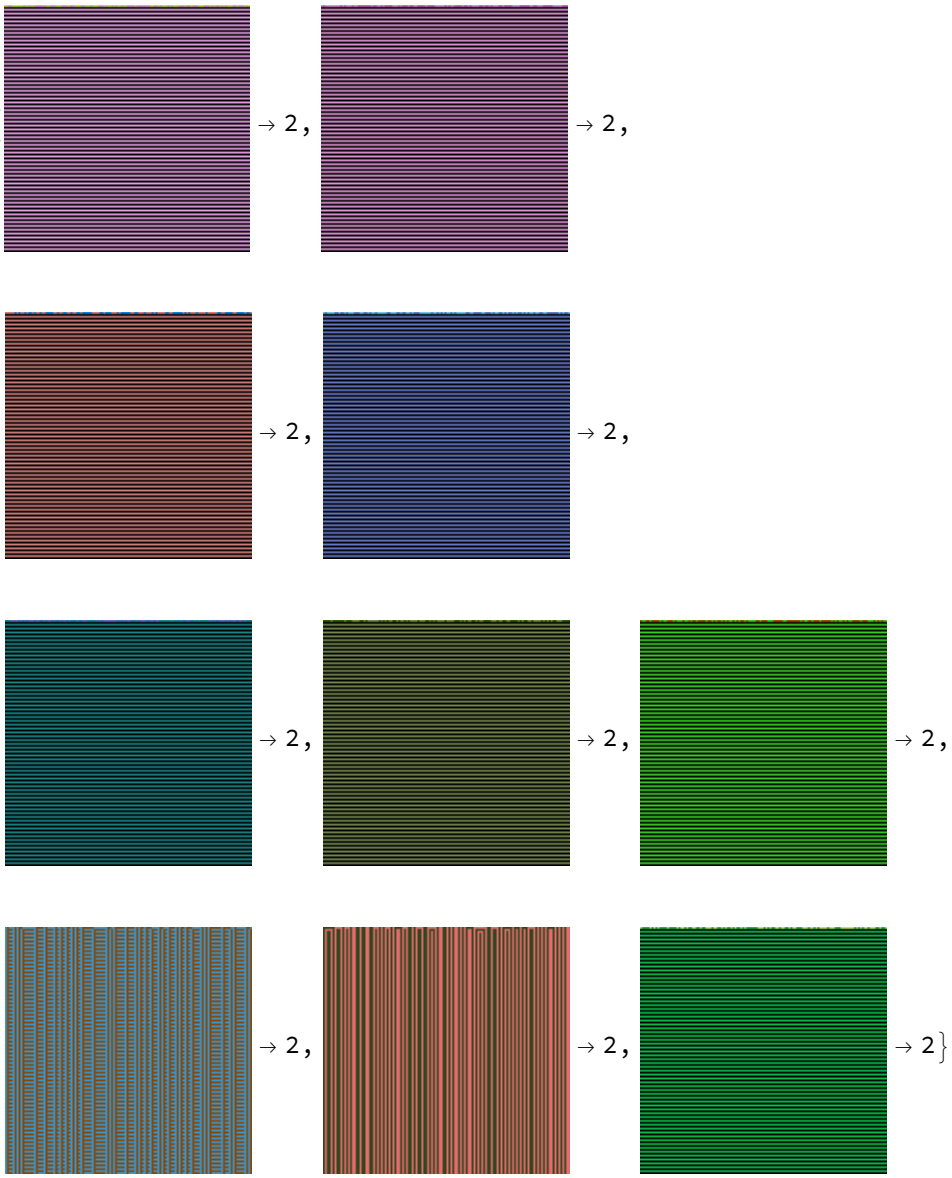


In[]:=
```
entropyImagesBigC = RandomSample[Keys[fullTestSetBigC], 500];
entropiesBigC = netECA13[entropyImagesBigC, "Entropy"];
highEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, -10]]];
lowEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, 10]]];
Thread[highEntBigC → netECA13[highEntBigC]]
Thread[lowEntBigC → netECA13[lowEntBigC]]
```

Out[•]=



Out[ ]=



Network XIV - BatchNorm, 1024 linear, dropout

In[ ]:= `netECA14 = netEightCC512drop[128, 128]`

Out[ ]= NetChain[

		image
	Input	array (size: 3 × 128 × 128)
conv1	ConvolutionLayer	array (size: 24 × 126 × 126)
bat1	BatchNormalizationLayer	array (size: 24 × 126 × 126)
ramp1	Ramp	array (size: 24 × 126 × 126)
conv2	ConvolutionLayer	array (size: 16 × 125 × 124)
bat2	BatchNormalizationLayer	array (size: 16 × 125 × 124)
ramp2	Ramp	array (size: 16 × 125 × 124)
conv3	ConvolutionLayer	array (size: 24 × 123 × 122)
bat3	BatchNormalizationLayer	array (size: 24 × 123 × 122)
ramp3	Ramp	array (size: 24 × 123 × 122)
pooling	PoolingLayer	array (size: 24 × 4 × 11)
flatten	FlattenLayer	vector (size: 1056)
linear	LinearLayer	vector (size: 1024)
drop2	DropoutLayer	vector (size: 1024)
linear2	LinearLayer	vector (size: 4)
softmax	SoftmaxLayer	vector (size: 4)
	Output	class

]

```
netECA14 = NetTrain[netECA14, fullTrainingBigC13,
  MaxTrainingRounds → 20, BatchSize → 256 * 4, TargetDevice → "CPU",
  TrainingProgressCheckpointing → {"Directory", dir}]
```

In[•]:=
```
dir = SetDirectory[NotebookDirectory[]]
```

Out[•]=
```
/Users/thorsilver/Downloads/Wolfram notebooks
```

In[•]:=
```
netECA14 = Import["netECA14-r20.wlnet"]
```

Out[•]=
NetChain[

	Input	image array (size: 3 × 128 × 128)
conv1	ConvolutionLayer	array (size: 24 × 126 × 126)
bat1	BatchNormalizationLayer	array (size: 24 × 126 × 126)
ramp1	Ramp	array (size: 24 × 126 × 126)
conv2	ConvolutionLayer	array (size: 16 × 125 × 124)
bat2	BatchNormalizationLayer	array (size: 16 × 125 × 124)
ramp2	Ramp	array (size: 16 × 125 × 124)
conv3	ConvolutionLayer	array (size: 24 × 123 × 122)
bat3	BatchNormalizationLayer	array (size: 24 × 123 × 122)
ramp3	Ramp	array (size: 24 × 123 × 122)
pooling	PoolingLayer	array (size: 24 × 4 × 11)
flatten	FlattenLayer	vector (size: 1056)
linear	LinearLayer	vector (size: 1024)
drop2	DropoutLayer	vector (size: 1024)
linear2	LinearLayer	vector (size: 4)
softmax	SoftmaxLayer	vector (size: 4)
	Output	class

]

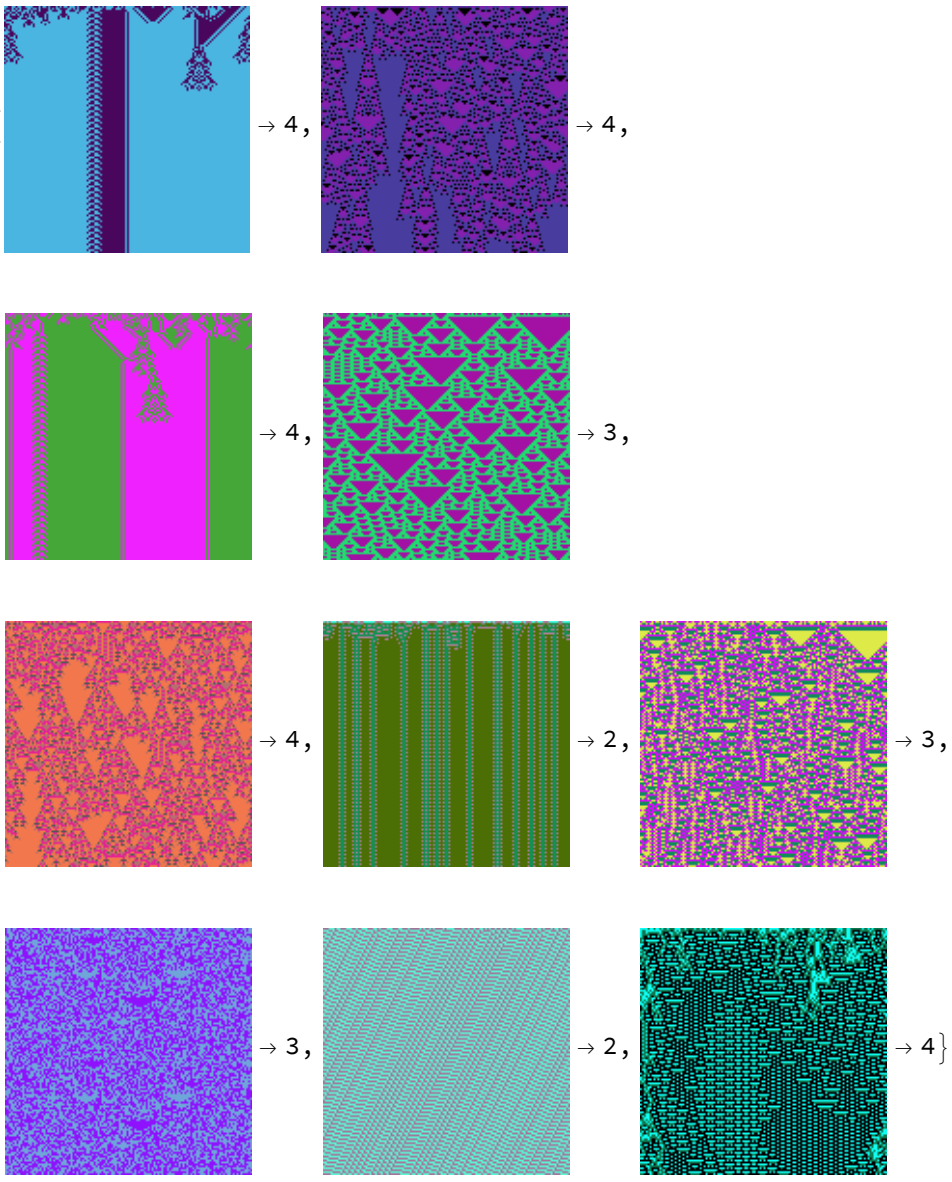
Generating test data for Network XIV

In[•]:=
```
testDataECABigC = dataC[128, 128, 1024];
testData2TBigC = genData2r2C[128, 128, 1024];
testData3TBigC = data3T2C[128, 128, 1024];
testData4TBigC = data4TC[128, 128, 1024];
testData5TBigC = genData5TCC[128, 128, 1024];
fullTestSetBigC = Join[testDataECABigC,
   testData2TBigC, testData3TBigC, testData4TBigC, testData5TBigC];
Length[fullTestSetBigC]
```

Out[•]=
```
10 240
```

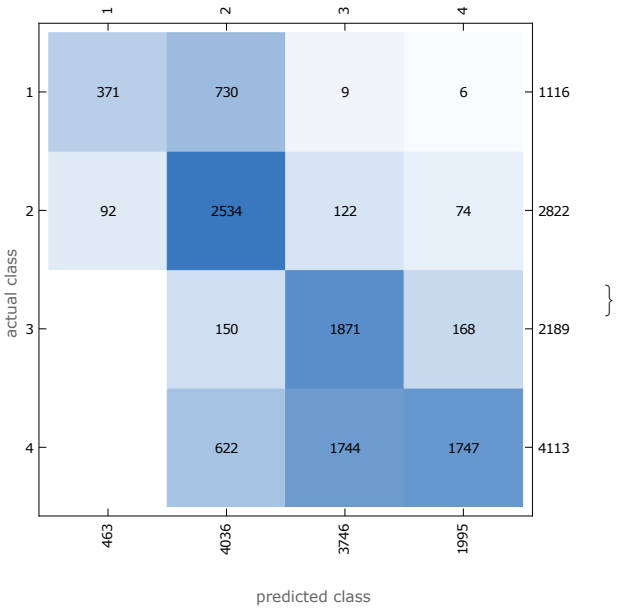
In[•]:= `RandomSample[fullTestSetBigC, 10]`

Out[•]=

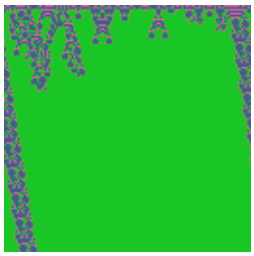


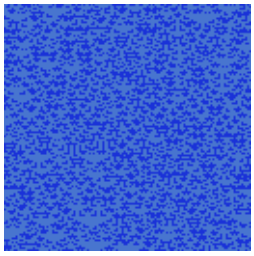
```
In[•]:= NetMeasurements[netECA14, fullTestSetBigC,
         {"Accuracy", "Precision", "ConfusionMatrixPlot"}]
```

```
Out[•]= {0.637012, ⟨| 1 → 0.801296, 2 → 0.627849, 3 → 0.499466, 4 → 0.875689 |⟩,
```

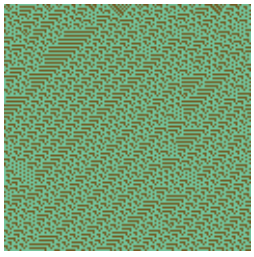


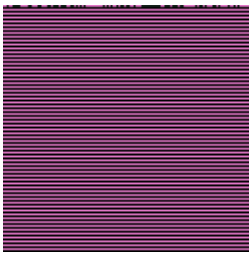
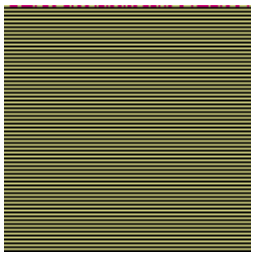

```
In[•]:= entropyImagesBigC = RandomSample[Keys[fullTestSetBigC], 500];
        entropiesBigC = netECA14[entropyImagesBigC, "Entropy"];
        highEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, -10]]];
        lowEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, 10]]];
        Thread[highEntBigC → netECA14[highEntBigC]]
        Thread[lowEntBigC → netECA14[lowEntBigC]]
```

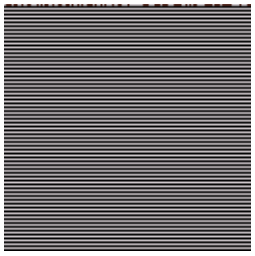
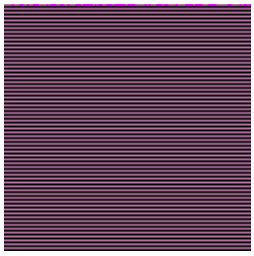
Out[•]= {  → 3,  → 4,

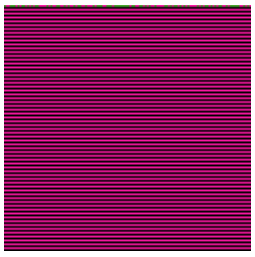
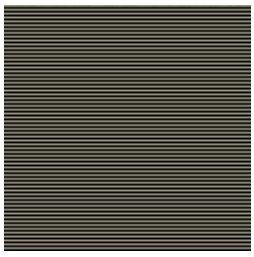
 → 2,  → 3,

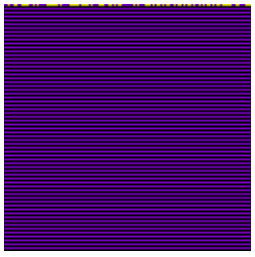
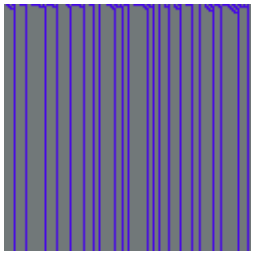
 → 3,  → 2,  → 3,

 → 2,  → 2,  → 3}

Out[ ]= {  → 2,  → 2,

 → 2,  → 2,

 → 2,  → 2,  → 2,

 → 2,  → 2,  → 2 }

Network XV - Transfer learning with pre-trained image recognition net (VGG-16)

```
In[•]:= netECA15 = NetModel["VGG-16 Trained on ImageNet Competition Data"]
```

Out[•]= NetChain[

	Input	image array (size: 3 × 224 × 224)
conv1_1	ConvolutionLayer	array (size: 64 × 224 × 224)
relu1_1	Ramp	array (size: 64 × 224 × 224)
conv1_2	ConvolutionLayer	array (size: 64 × 224 × 224)
relu1_2	Ramp	array (size: 64 × 224 × 224)
pool1	PoolingLayer	array (size: 64 × 112 × 112)
conv2_1	ConvolutionLayer	array (size: 128 × 112 × 112)
relu2_1	Ramp	array (size: 128 × 112 × 112)
conv2_2	ConvolutionLayer	array (size: 128 × 112 × 112)
relu2_2	Ramp	array (size: 128 × 112 × 112)
pool2	PoolingLayer	array (size: 128 × 56 × 56)
conv3_1	ConvolutionLayer	array (size: 256 × 56 × 56)
relu3_1	Ramp	array (size: 256 × 56 × 56)
conv3_2	ConvolutionLayer	array (size: 256 × 56 × 56)
relu3_2	Ramp	array (size: 256 × 56 × 56)
conv3_3	ConvolutionLayer	array (size: 256 × 56 × 56)
relu3_3	Ramp	array (size: 256 × 56 × 56)
pool3	PoolingLayer	array (size: 256 × 28 × 28)
conv4_1	ConvolutionLayer	array (size: 512 × 28 × 28)
relu4_1	Ramp	array (size: 512 × 28 × 28)
conv4_2	ConvolutionLayer	array (size: 512 × 28 × 28)
relu4_2	Ramp	array (size: 512 × 28 × 28)
conv4_3	ConvolutionLayer	array (size: 512 × 28 × 28)
relu4_3	Ramp	array (size: 512 × 28 × 28)
pool4	PoolingLayer	array (size: 512 × 14 × 14)
conv5_1	ConvolutionLayer	array (size: 512 × 14 × 14)
relu5_1	Ramp	array (size: 512 × 14 × 14)
conv5_2	ConvolutionLayer	array (size: 512 × 14 × 14)
relu5_2	Ramp	array (size: 512 × 14 × 14)
conv5_3	ConvolutionLayer	array (size: 512 × 14 × 14)
relu5_3	Ramp	array (size: 512 × 14 × 14)
pool5	PoolingLayer	array (size: 512 × 7 × 7)
flatten_0	FlattenLayer	vector (size: 25088)
fc6	LinearLayer	vector (size: 4096)
relu6	Ramp	vector (size: 4096)
drop6	DropoutLayer	vector (size: 4096)
fc7	LinearLayer	vector (size: 4096)
relu7	Ramp	vector (size: 4096)
drop7	DropoutLayer	vector (size: 4096)
fc8	LinearLayer	vector (size: 1000)
prob	SoftmaxLayer	vector (size: 1000)
	Output	class

]

```
In[•]:= subNet = NetTake[netECA15, {"conv1_1", "flatten_0"}]
```

Out[•]= NetChain[

Input port:	image
Output port:	vector (size: 25088)
Number of layers:	32

]

```
In[•]:= joinedNet = NetJoin[subNet,
  NetChain@<|"linear_new" → LinearLayer[1024], "linear_out" → LinearLayer[4],
    "prob" → SoftmaxLayer[]|>, "Output" → NetDecoder[{"Class", Range[1, 4]}]]
```

Out[•]= NetChain[

uninitialized

Input port:	image
Output port:	class
Number of layers:	35

]

```
In[•]:= netECA15final =
         NetPrepend[joinedNet, {"augment" → ImageAugmentationLayer[{224, 224}]},
          "Input" → NetExtract[joinedNet, "Input"]]
```

```
Out[•]= NetChain[ uninitialized
                  Input port:          image
                  Output port:         class
                  Number of layers:    36 ]
```

```
In[•]:= dataECA15 = dataC[224, 224, 8192];
```

```
In[•]:= dataTotalistic2BigC15 = genData2r2C[224, 224, 1024];
```

```
In[•]:= dataTotalistic3BigC15 = data3T2C[224, 224, 512];
```

```
In[•]:= dataTotalistic4BigC15 = data4TC[224, 224, 512];
```

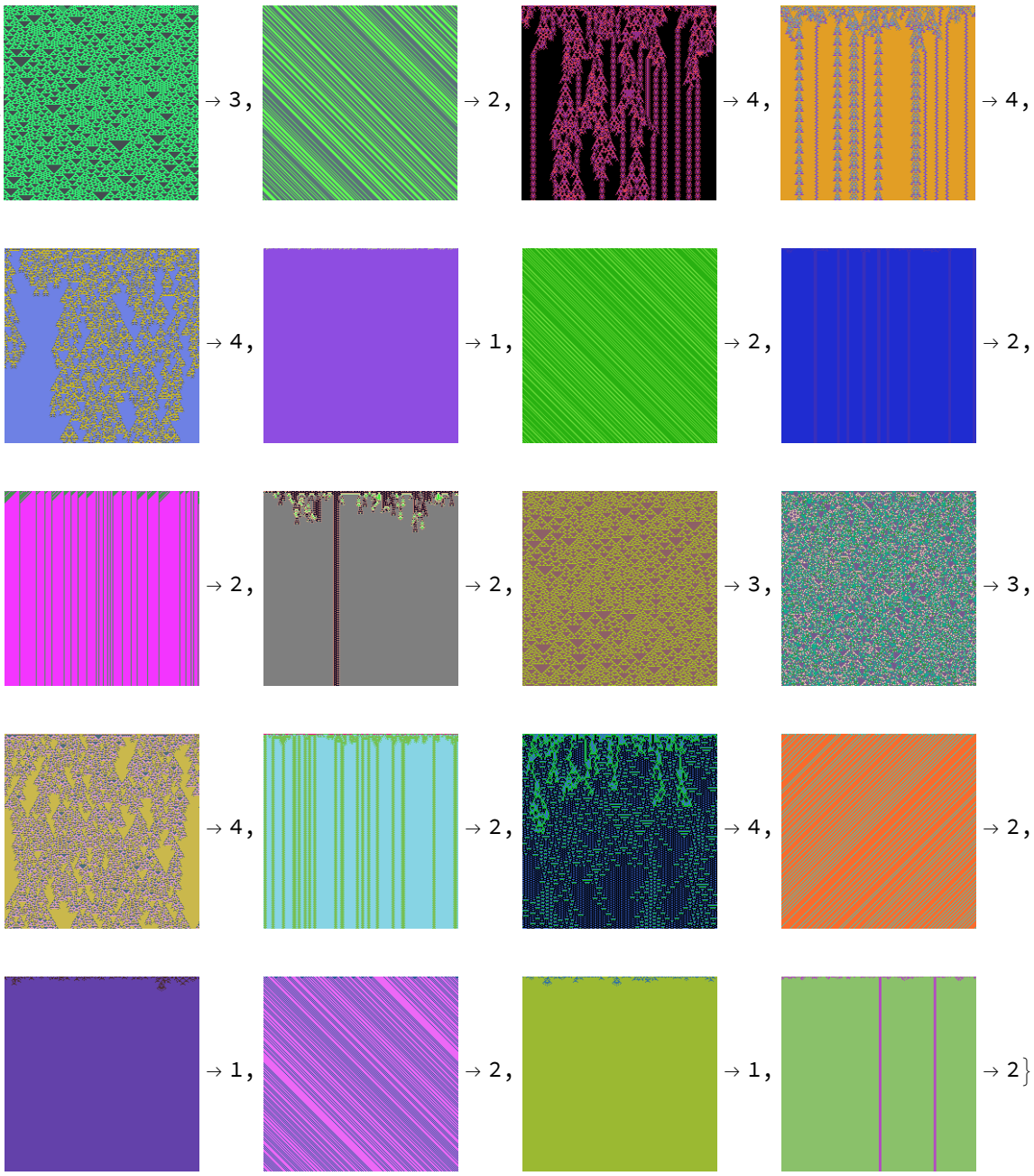
```
In[•]:= dataTotalistic5BigC15 = genData5TCC[224, 224, 1024];
```

```
In[•]:= fullTrainingBigC15 = Join[dataECA15, dataTotalistic2BigC15,
           dataTotalistic3BigC15, dataTotalistic4BigC15, dataTotalistic5BigC15];
        Length[fullTrainingBigC15]
```

```
Out[•]= 16 384
```

In[•]:=
```
RandomSample[fullTrainingBigC15, 20]
```

Out[•]=

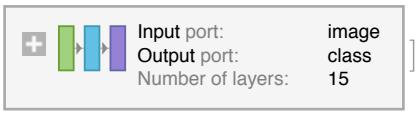


In[•]:=
```
netECA15final = NetTrain[netECA15final, fullTrainingBigC15,
  MaxTrainingRounds → 5, BatchSize → 256 * 4, TargetDevice → "CPU",
  TrainingProgressCheckpointing → {"Directory", dir},
  LearningRateMultipliers → {"linear_new" → 1, "linear_out" → 1, _ → 0}]
```

Network XVI - Three convolutions, dropout on linear only, BatchNorm

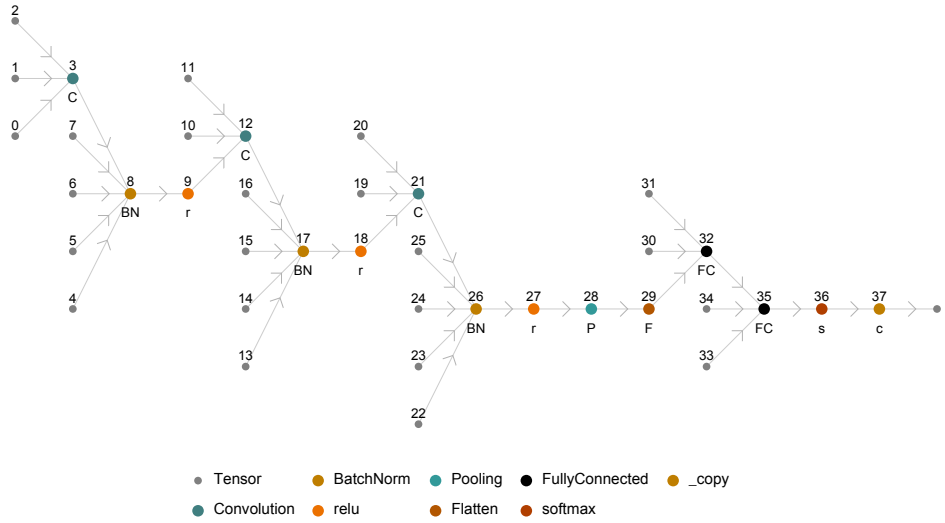
In[•]:=
```
netECA16 = netNineCC512drop[128, 128]
```

Out[•]=

NetChain[]

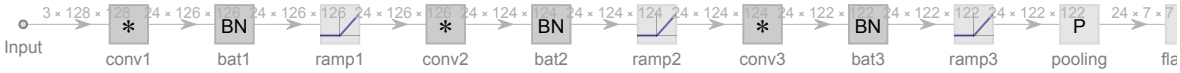
In[•]:=
```
NetInformation[netECA16, "MXNetNodeGraphPlot"]
```

Out[•]=



In[•]:=
```
NetInformation[netECA16, "SummaryGraphic"]
```

Out[•]=



In[•]:=
```
dataECA16 = dataC[128, 128, 8192];
```

In[•]:=
```
dataTotalistic2BigC16 = genData2r2C[128, 128, 1024];
```

In[•]:=
```
dataTotalistic3BigC16 = data3T2C[128, 128, 1024];
```

In[•]:=
```
dataTotalistic4BigC16 = data4TC[128, 128, 1024];
```

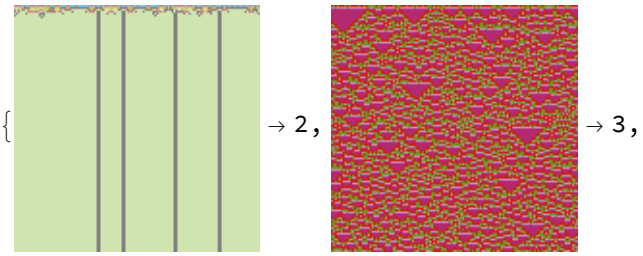
In[•]:=
```
dataTotalistic5BigC16 = genData5TCC[128, 128, 4096];
```

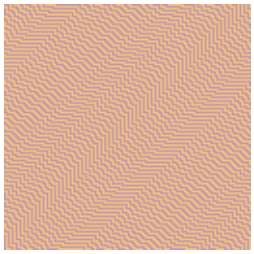
In[•]:=
```
fullTrainingBigC16 = Join[dataECA16, dataTotalistic2BigC16,
   dataTotalistic3BigC16, dataTotalistic4BigC16, dataTotalistic5BigC16];
Length[fullTrainingBigC16]
```

Out[•]=
```
26 624
```

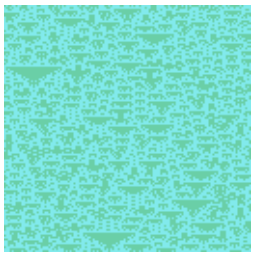
In[•]:=
```
RandomSample[fullTrainingBigC16, 20]
```

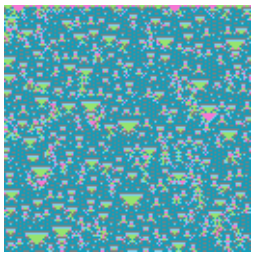
Out[•]=

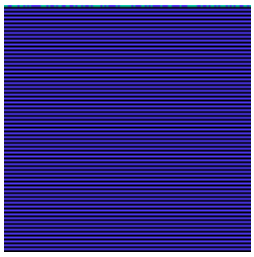


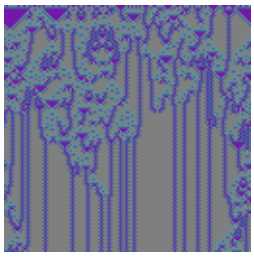

→ 2,

→ 2,

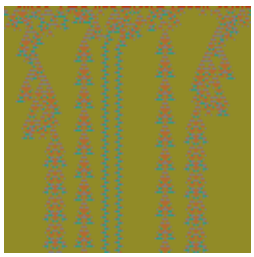
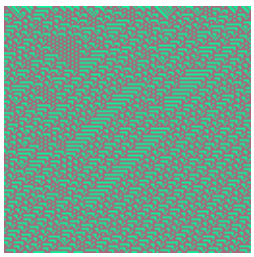
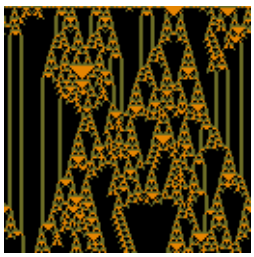
→ 1,

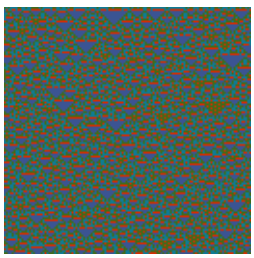
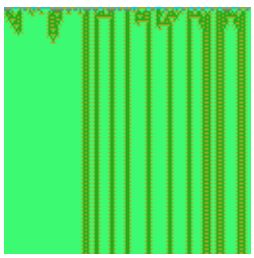

→ 3,

→ 2,

→ 3,

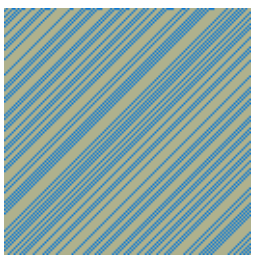

→ 2,

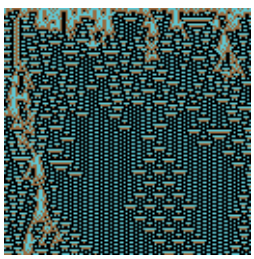
→ 1,

→ 4,


→ 4,

→ 3,

→ 4,


→ 3,

→ 2,

→ 1,


→ 2,

→ 2,

→ 4}

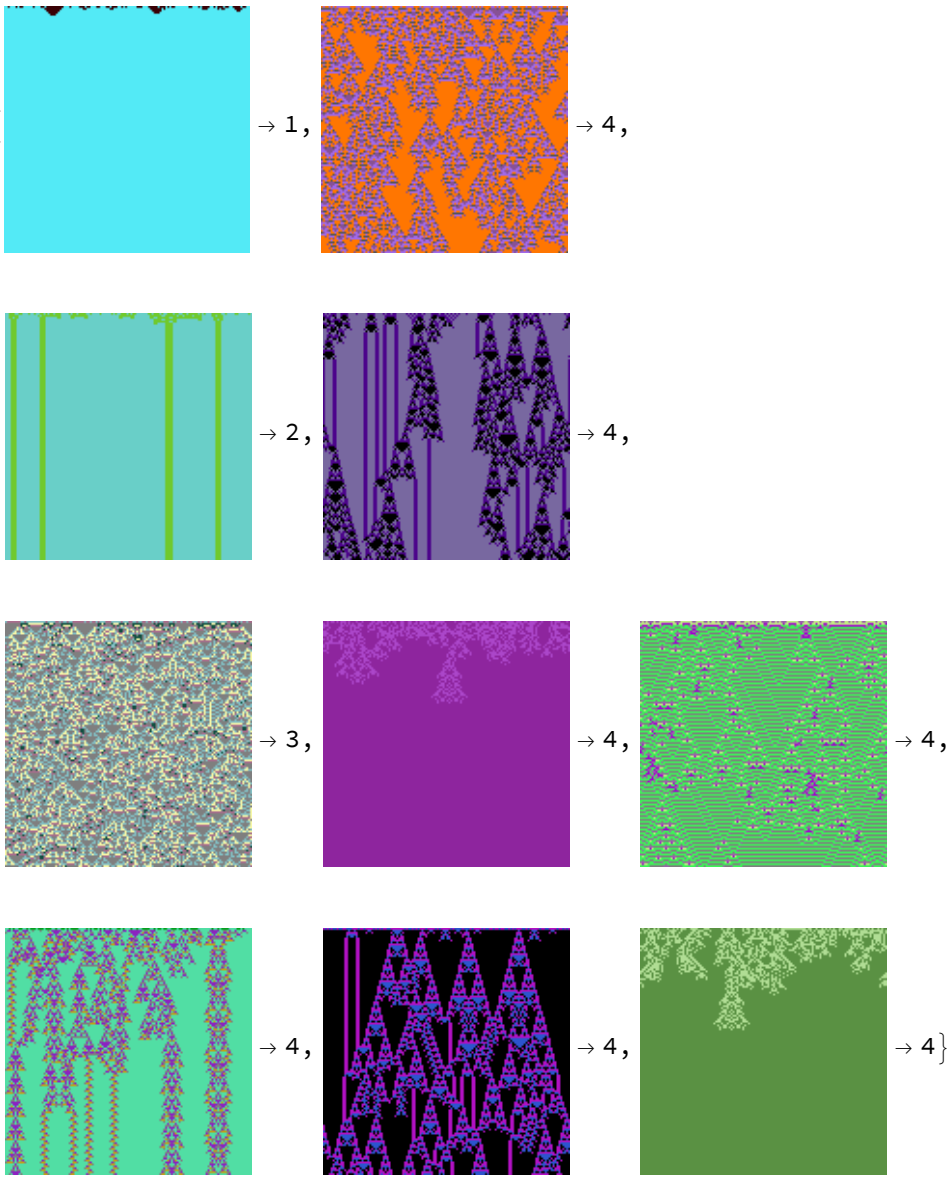
```
In[•]:= dir = SetDirectory[NotebookDirectory[]]
Out[•]= /home/esilverman/Documents

In[•]:= netECA16 = NetTrain[netECA16, fullTrainingBigC16,
          MaxTrainingRounds → 200, BatchSize → 256, TargetDevice → "GPU",
          TrainingProgressCheckpointing → {"Directory", dir}]
Out[•]= NetChain[ <image> Input port: image
                  Output port: class
                  Number of layers: 15 ]

        netECA16 = Import["netECA16-r20.wlnet"]

        netECA16 = NetTrain[netECA16, fullTrainingBigC16,
          MaxTrainingRounds → 20, BatchSize → 256 * 4, TargetDevice → "CPU",
          TrainingProgressCheckpointing → {"Directory", dir}]
```

Generate test data for Network XVI

```
In[•]:= dir = SetDirectory[NotebookDirectory[]]
Out[•]= /Users/thorsilver/Downloads/Wolfram notebooks

In[•]:= netECA16 = Import["netECA16-r20.wlnet"]
Out[•]= NetChain[ <image> Input port: image
                  Output port: class
                  Number of layers: 15 ]

In[•]:= testDataECABigC = dataC[128, 128, 1024];
        testData2TBigC = genData2r2C[128, 128, 1024];
        testData3TBigC = data3T2C[128, 128, 1024];
        testData4TBigC = data4TC[128, 128, 1024];
        testData5TBigC = genData5TCC[128, 128, 1024];
        fullTestSetBigC = Join[testDataECABigC,
           testData2TBigC, testData3TBigC, testData4TBigC, testData5TBigC];
        Length[fullTestSetBigC]
Out[•]= 10 240
```

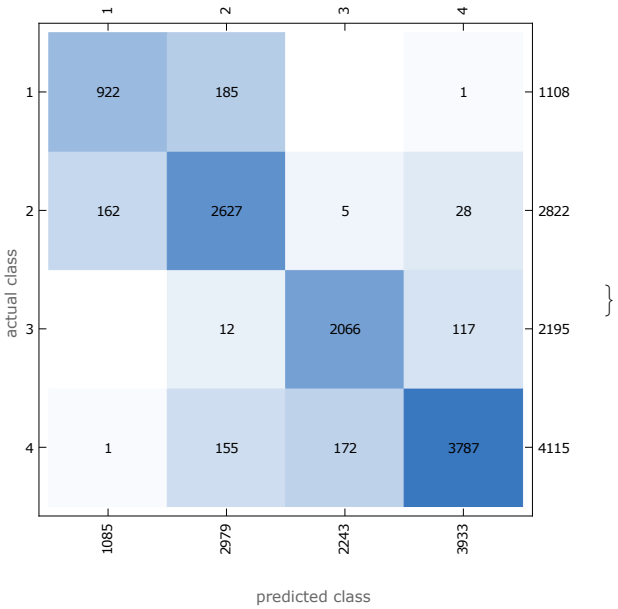
In[•]:= `RandomSample[fullTestSetBigC, 10]`

Out[•]=

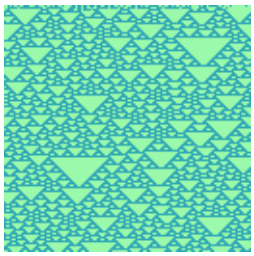


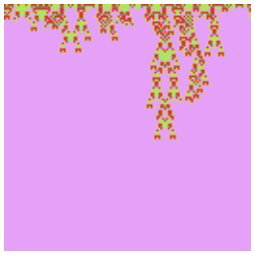
```
In[•]:= NetMeasurements[netECA16, fullTestSetBigC,
         {"Accuracy", "Precision", "ConfusionMatrixPlot"}]
```

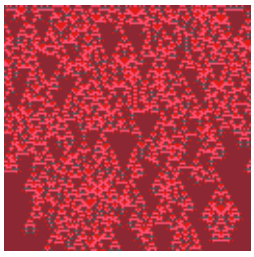
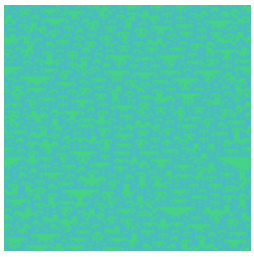
```
Out[•]= {0.918164, ⟨|1 → 0.84977, 2 → 0.88184, 3 → 0.921088, 4 → 0.962878|⟩,
```

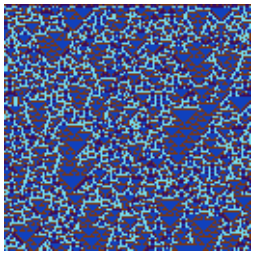


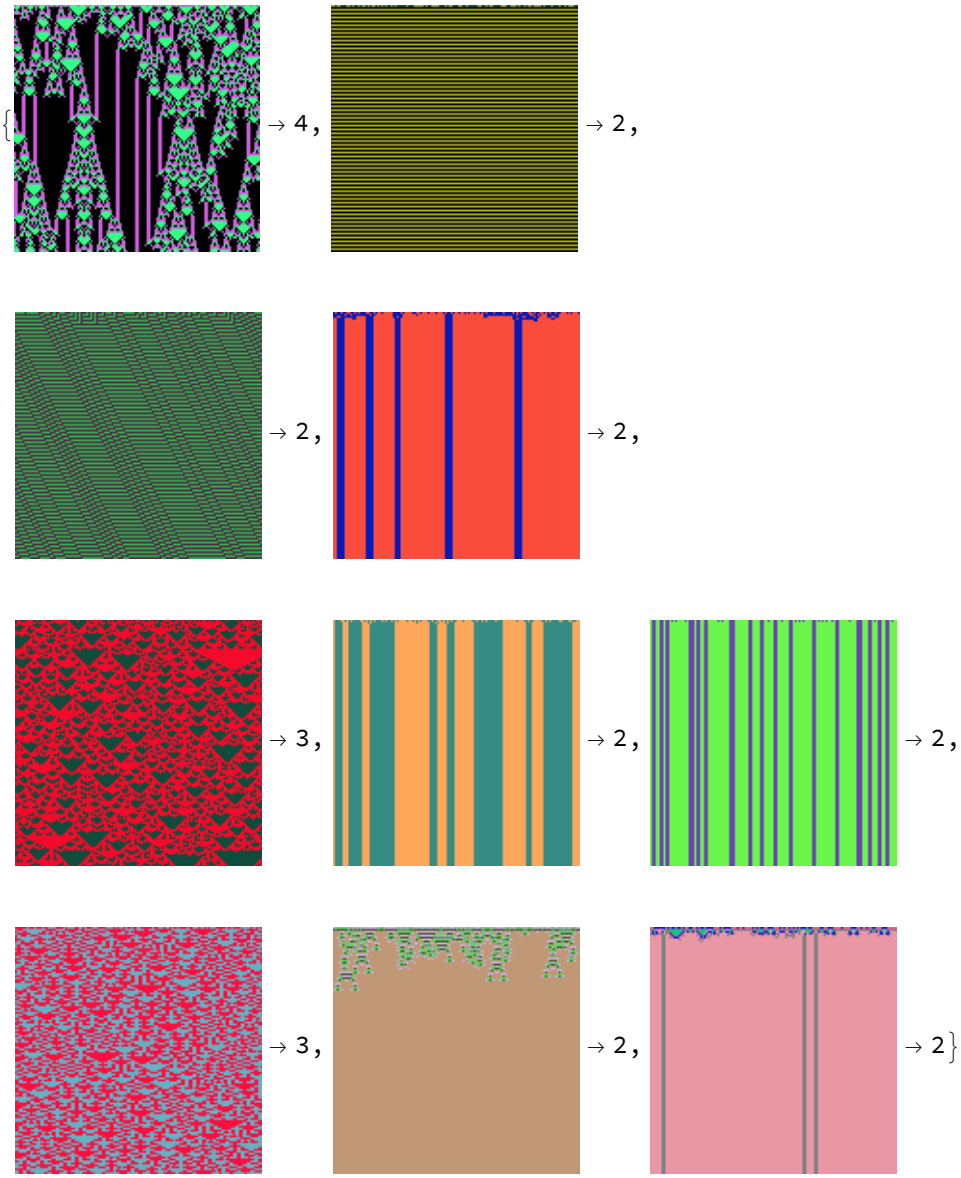

```
In[•]:= entropyImagesBigC = RandomSample[Keys[fullTestSetBigC], 500];
        entropiesBigC = netECA16[entropyImagesBigC, "Entropy"];
        highEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, -10]]];
        lowEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, 10]]];
        Thread[highEntBigC → netECA16[highEntBigC]]
        Thread[lowEntBigC → netECA16[lowEntBigC]]
```

Out[•]= {  → 1,  → 3,

 → 4,  → 2,

 → 1,  → 3,  → 4,

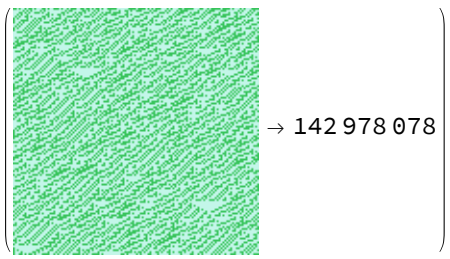
 → 3,  → 2,  → 4 }

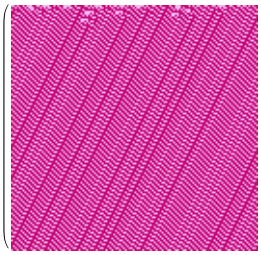
Out[•]= 

Testing Network XVI on unseen CA rule spaces

2-colour non-totalistic, range 2

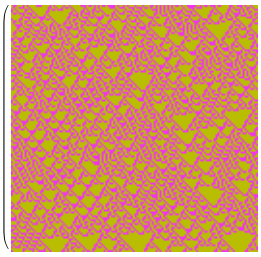
In[•]:=
```
test4Data2kr2C16 = datak2r2C[128, 128, 8];
Thread[
 test4Data2kr2C16 → netECA16[Keys@test4Data2kr2C16, {"TopProbabilities", 2}]]
```

Out[•]=  → 142 978 078 → {4 → 0.0000385332, 3 → 0.999961},

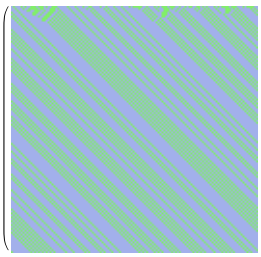


→ 2 651 048 833 → $\{4 \to 8.69455 \times 10^{-12}, 2 \to 1.\}$,

→ 2 132 867 963 → $\{4 \to 2.86202 \times 10^{-17}, 2 \to 1.\}$,

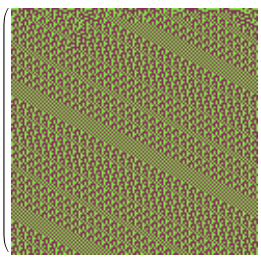


→ 3 644 758 968 → $\{4 \to 6.11899 \times 10^{-7}, 3 \to 0.999999\}$,

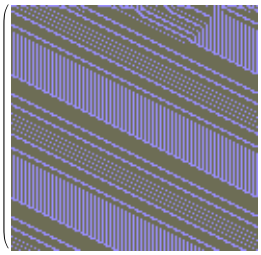


→ 1 762 420 096 → $\{1 \to 2.34707 \times 10^{-9}, 2 \to 1.\}$,

→ 1 983 429 391 → $\{4 \to 0.0547227, 3 \to 0.945277\}$,



→ 3 013 553 323 → $\{3 \to 0.0109364, 2 \to 0.989064\}$,

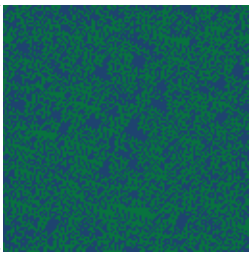


→ 4 222 841 103 → {4 → 0.406794, 3 → 0.593206}

2-colour non-totalistic, range 3

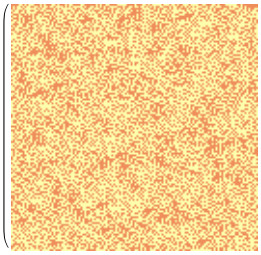
In[•]:=
```
test4Data2kr3C16 = datak2r3NT[128, 128, 8];
Thread[
 test4Data2kr3C16 → netECA16[Keys@test4Data2kr3C16, {"TopProbabilities", 2}]]
```

Out[•]=



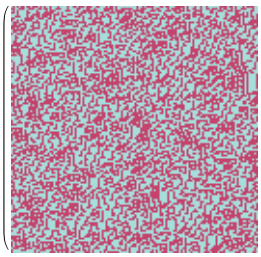
→ 326 920 608 662 421 742 840 307 341 423 521 605 984 →

{4 → 0.250823, 3 → 0.749175},



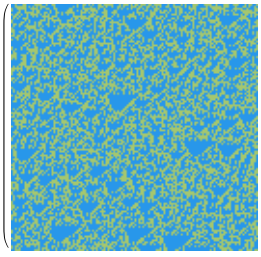
→ 207 378 363 536 986 723 396 466 725 374 349 770 886 →

$\{4 \to 3.99297 \times 10^{-14}, 3 \to 1.\}$,



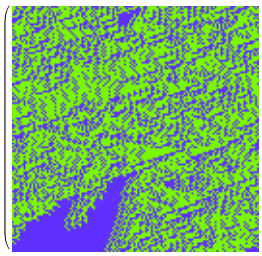
→ 208 879 936 260 575 914 948 311 642 807 908 540 203 →

$\{4 \to 1.58015 \times 10^{-11}, 3 \to 1.\}$,



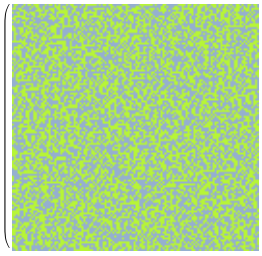
→ 287 306 647 832 264 924 895 832 728 648 359 695 369 →

$\{4 \to 1.21845 \times 10^{-8}, 3 \to 1.\},$



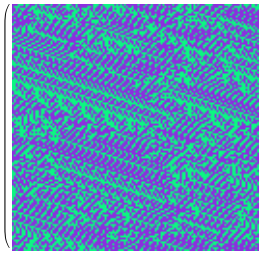
$\to 229\,589\,239\,336\,289\,801\,086\,527\,228\,211\,518\,173\,928 \to$

$\{3 \to 0.0173989, 4 \to 0.982601\},$



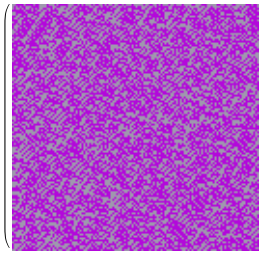
$\to 25\,263\,864\,036\,549\,856\,421\,518\,677\,057\,185\,002\,153 \to$

$\{4 \to 2.486 \times 10^{-11}, 3 \to 1.\},$



$\to 122\,573\,209\,377\,430\,367\,268\,072\,050\,742\,932\,826\,218 \to$

$\{4 \to 1.46881 \times 10^{-9}, 3 \to 1.\},$



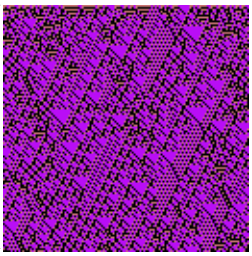
$\to 120\,291\,014\,848\,530\,508\,056\,036\,077\,228\,147\,332\,137 \to$

$\{4 \to 0.00683298, 3 \to 0.993167\}\}$

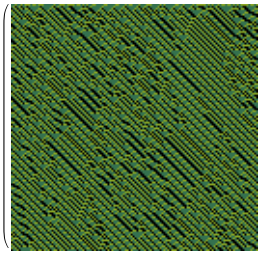
3-colour non-totalistic, range 1

In[•]:=
```
test4Data3kr1C16 = datak3r1NT[128, 128, 8];
Thread[
 test4Data3kr1C16 → netECA16[Keys@test4Data3kr1C16, {"TopProbabilities", 2}]]
```

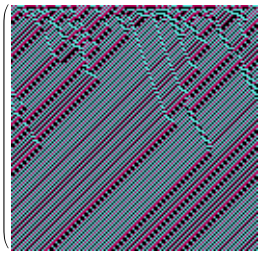
Out[•]= {



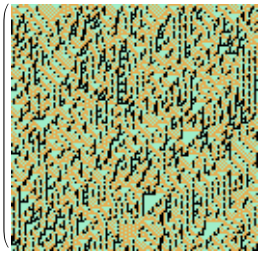
→ 4 431 477 695 805 → {4 → 0.000746188, 3 → 0.999254},



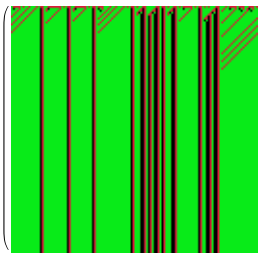
→ 1 627 958 441 874 → {4 → 0.00025369, 3 → 0.999746},



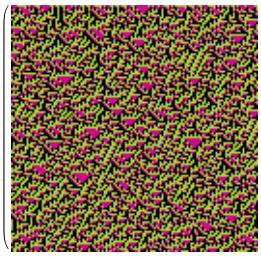
→ 4 241 674 451 024 → {3 → 0.194892, 2 → 0.805108},



→ 4 177 916 755 057 → $\{3 \to 9.07174 \times 10^{-18}, 4 \to 1.\}$,

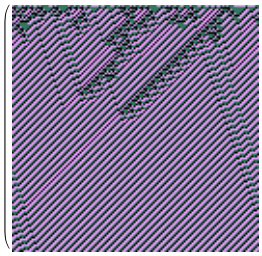


→ 2 504 235 138 103 → $\{4 \to 1.3375 \times 10^{-21}, 2 \to 1.\}$,



→ 2 281 646 033 785 → {4 → 0.164883, 3 → 0.835117},


→ 886 946 817 375 → {2 → 0.000352038, 1 → 0.999648},

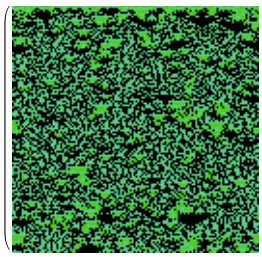

→ 1 468 391 136 669 → {4 → 1.85451 × 10^-11, 2 → 1.}}

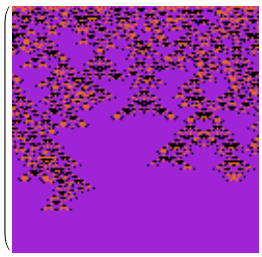
3-colour totalistic, range 2

In[•]:=
```
test4Data3kr2C16 = datak3r2C[128, 128, 8];
Thread[
 test4Data3kr2C16 → netECA16[Keys@test4Data3kr2C16, {"TopProbabilities", 2}]]
```

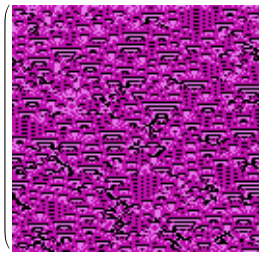
Out[•]=


→ 31 794 → {2 → 0.0000274564, 1 → 0.999973},


→ 154 722 → {4 → 3.53893 × 10^-6, 3 → 0.999996},

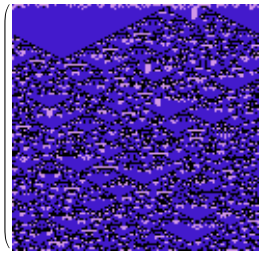

→ 47 093 → {3 → 0.0000226662, 4 → 0.999977},

→ 40 833 → {2 → 7.38958 × 10^-10, 1 → 1.},

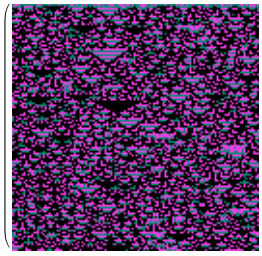


→ 70 499 → {4 → 9.14168 × 10^-7, 3 → 0.999999},

→ 104 031 → {2 → 0.00469642, 1 → 0.995304},



→ 102 416 → {4 → 0.00127827, 3 → 0.998722},

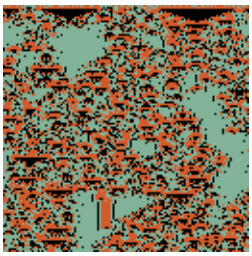


→ 143 812 → {3 → 0.00152229, 4 → 0.998478}}

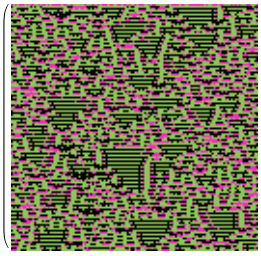
3-colour totalistic, range 3

In[•]:=
```
test4Data3kr3C16 = datak3r3C[128, 128, 8];
Thread[
 test4Data3kr3C16 → netECA16[Keys@test4Data3kr3C16, {"TopProbabilities", 2}]]
```

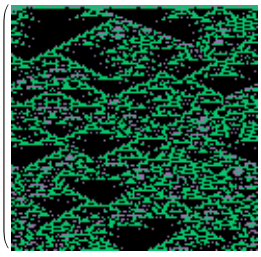
Out[•]= {



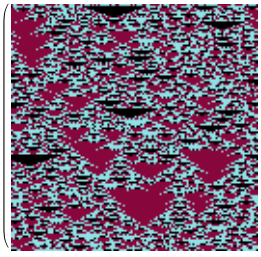
→ 9 694 493 | → {3 → 0.480724, 4 → 0.519276},



→ 1 266 350 | → {3 → 2.07073 × 10^-17, 4 → 1.},

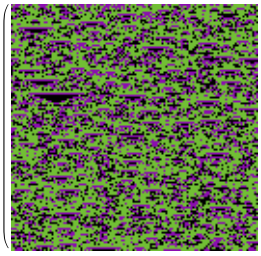


→ 10 922 251 | → {4 → 0.0000302967, 3 → 0.99997},

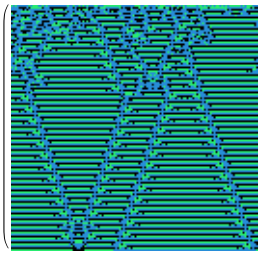


→ 10 284 081 | → {4 → 0.0000121386, 3 → 0.999988},

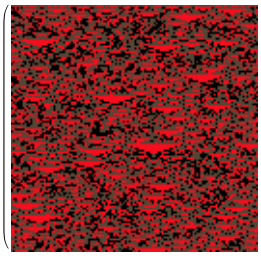
→ 3 664 255 | → {1 → 0.0137727, 2 → 0.986227},



→ 10 298 881 | → {4 → 0.000133186, 3 → 0.999867},



→ 8 621 297 → {3 → 5.17911 × 10^-10, 4 → 1.},

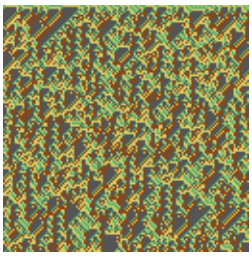


→ 11 392 150 → {4 → 8.14877 × 10^-14, 3 → 1.}}

4-colour non-totalistic, range 1

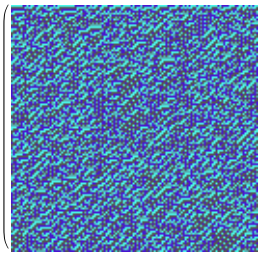
In[•]:=
```
test4Data4kr1C16 = datak4r1NT[128, 128, 8];
Thread[
 test4Data4kr1C16 → netECA16[Keys@test4Data4kr1C16, {"TopProbabilities", 2}]]
```

Out[•]=

{ 

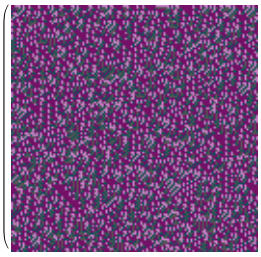
→ 154 080 220 988 097 676 666 997 866 552 654 645 473 →

{3 → 2.29402 × 10^-6, 4 → 0.999998},



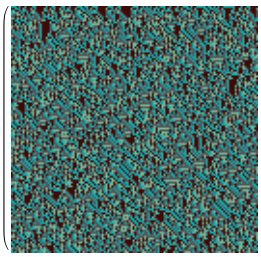
→ 23 699 455 383 307 433 676 732 305 926 546 946 154 →

{4 → 9.18698 × 10^-10, 3 → 1.},



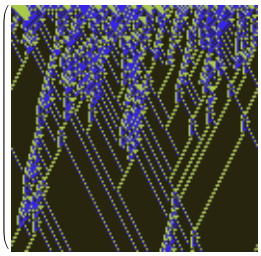
→ 128 473 503 291 830 537 978 738 932 215 015 934 320 →

{4 → 0.016884, 3 → 0.983116},



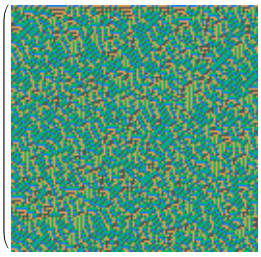
→ 229 632 577 374 973 873 063 824 352 556 638 470 668 →

$\{3 \to 3.66751 \times 10^{-6}, 4 \to 0.999996\}$,



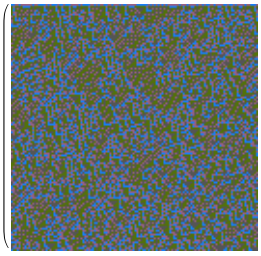
→ 296 751 325 089 499 848 049 286 011 129 052 334 280 →

$\{2 \to 0.0356663, 4 \to 0.964334\}$,



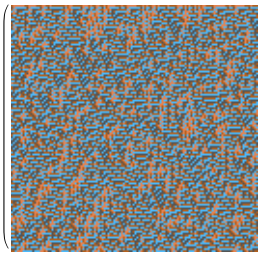
→ 58 389 931 388 288 805 968 545 394 973 250 265 077 →

$\{4 \to 0.392533, 3 \to 0.607467\}$,



→ 190 838 234 746 017 730 793 117 442 629 783 928 461 →

$\{3 \to 0.0000369307, 4 \to 0.999963\}$,



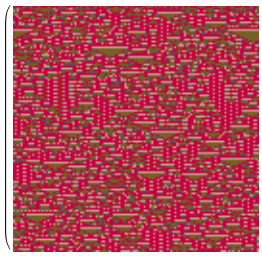
→ 203 920 243 365 735 713 208 234 812 082 196 839 807 →

$\{4 \to 0.00577653, 3 \to 0.994223\}\}$

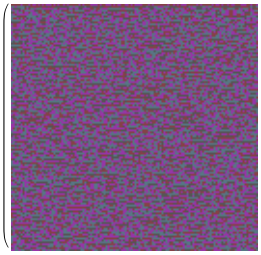
4-colour totalistic, range 2

```
In[•]:= test4Data4kr2C16 = datak4r2C[128, 128, 8];
        Thread[
         test4Data4kr2C16 → netECA16[Keys@test4Data4kr2C16, {"TopProbabilities", 2}]]
```

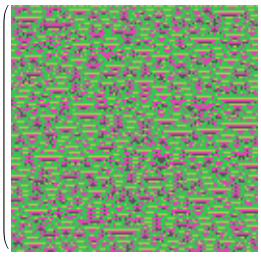
Out[•]=



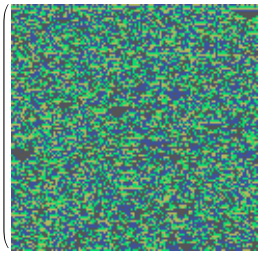
→ 25 517 204 → {4 → 1.29127 × 10^-13, 3 → 1.},



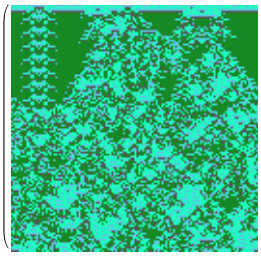
→ 3 053 925 273 → {4 → 0.00215091, 3 → 0.997849},



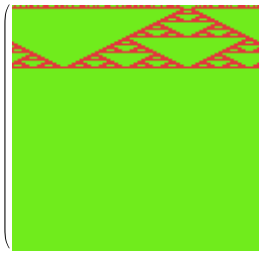
→ 2 735 868 989 → {4 → 0.000282149, 3 → 0.999718},



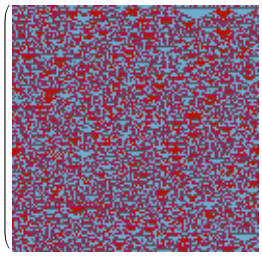
→ 1 440 927 950 → {4 → 0.0889018, 3 → 0.911098},



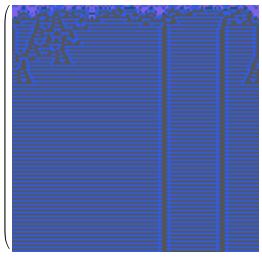
→ 3 727 816 705 → {3 → 2.78599 × 10^-7, 4 → 1.},



→ 818 963 457 → {4 → 4.45422 × 10^-19, 3 → 1.},



→ 3 948 742 311 → {4 → 2.06369 × 10^-10, 3 → 1.},

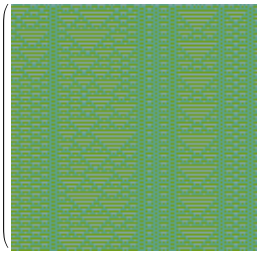


→ 1 159 108 912 → {4 → 0.431018, 2 → 0.568975}}

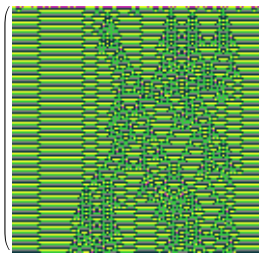
5-colour totalistic, range 1

In[•]:=
```
test4Data5kr1C16 = data5T2C[8, 128, 128];
Thread[
 test4Data5kr1C16 → netECA16[Keys@test4Data5kr1C16, {"TopProbabilities", 2}]]
```

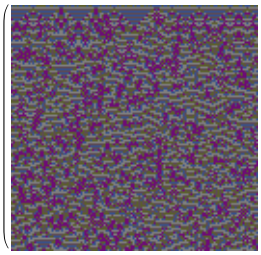
Out[•]=



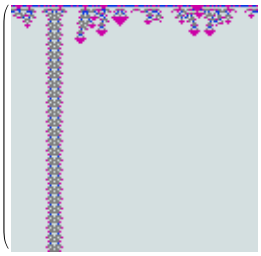
→ 81 353 109 → {4 → 4.44391 × 10^-7, 2 → 1.},



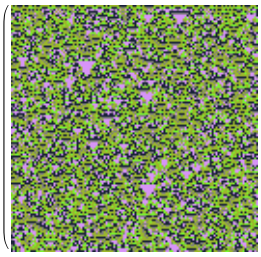
→ 626 536 724 → {3 → 3.46291 × 10^-8, 4 → 1.},



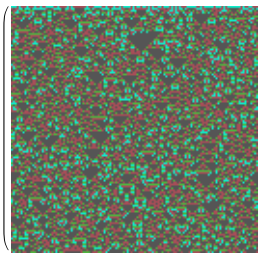
$\to 129\,595\,314 \to \{4 \to 0.00257287, 3 \to 0.997427\},$



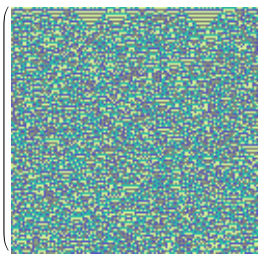
$\to 513\,885\,470 \to \left\{1 \to 1.41572 \times 10^{-11}, 2 \to 1.\right\},$



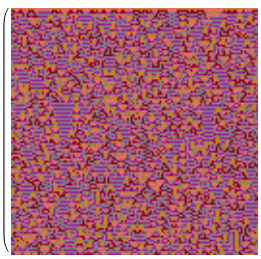
$\to 494\,894\,021 \to \{3 \to 0.0136503, 4 \to 0.98635\},$



$\to 459\,414\,632 \to \{4 \to 0.0000813289, 3 \to 0.999919\},$



$\to 327\,281\,621 \to \left\{4 \to 2.29489 \times 10^{-8}, 3 \to 1.\right\},$

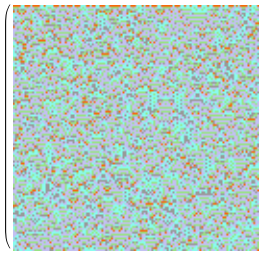


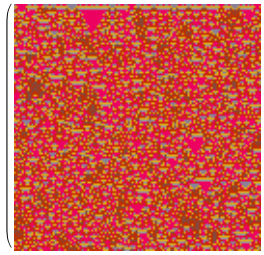
$\to 503\,044\,041 \to \{4 \to 0.191949, 3 \to 0.808051\}\}$

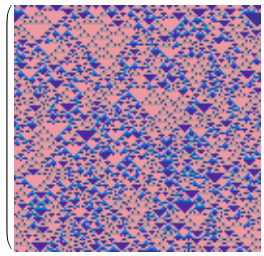
6-colour totalistic, range 1

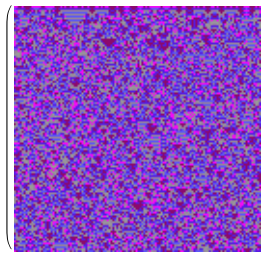
In[•]:=
```
test4Data6kr1C16 = data6TC[8, 128, 128];
Thread[
 test4Data6kr1C16 → netECA16[Keys@test4Data6kr1C16, {"TopProbabilities", 2}]]
```

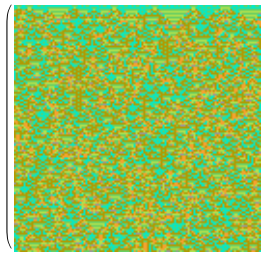
Out[•]=

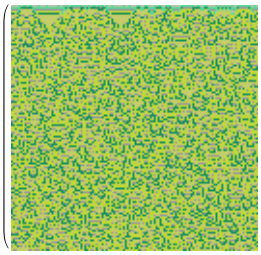

→ 1 522 715 109 251 → {4 → 2.02852 × 10^-8, 3 → 1.},

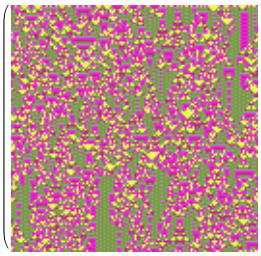

→ 1 026 953 898 330 → {4 → 2.88279 × 10^-8, 3 → 1.},

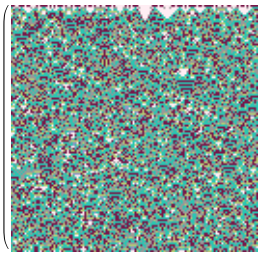

→ 1 583 652 682 → {3 → 0.429972, 4 → 0.570028},


→ 2 123 073 201 165 → {4 → 6.23239 × 10^-10, 3 → 1.},


→ 341 591 565 791 → {4 → 0.00212154, 3 → 0.997878},


→ 2 568 539 246 083 → {4 → 0.00197237, 3 → 0.998028},

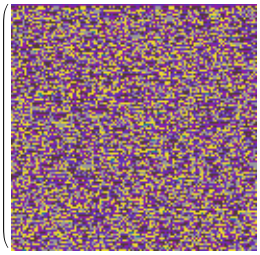

→ 1 213 730 554 155 → {4 → 0.0020281, 3 → 0.997972},

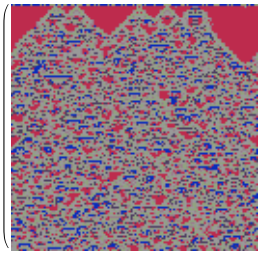

→ 389 841 312 036 → {4 → 2.91693 × 10^-11, 3 → 1.}}

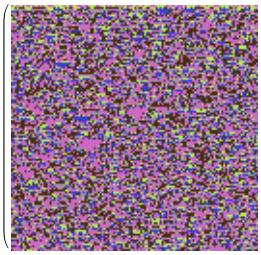
6-colour totalistic, range 2

In[•]:=
```
test4Data6kr2C16 = data6T2C[8, 128, 128];
Thread[
 test4Data6kr2C16 → netECA16[Keys@test4Data6kr2C16, {"TopProbabilities", 2}]]
```

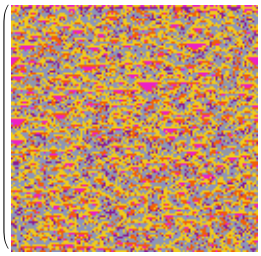
Out[•]=


→ 46 177 535 535 728 053 148 → {4 → 6.75757 × 10^-8, 3 → 1.},

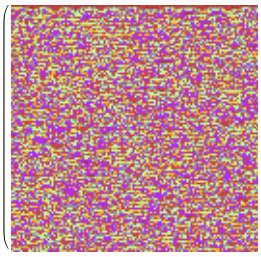

→ 35 643 164 656 729 746 413 → {4 → 4.68349 × 10^-15, 3 → 1.},



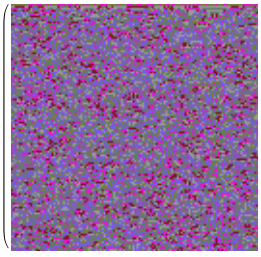
→ 151 294 335 263 255 298 785 → {4 → 0.0673459, 3 → 0.932654},



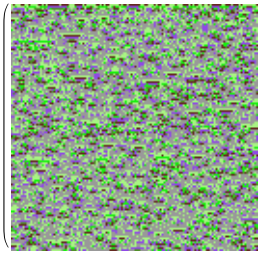
→ 8 803 703 818 914 948 546 → {4 → 0.00560205, 3 → 0.994398},



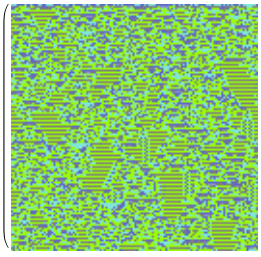
→ 46 723 275 025 483 150 950 → {4 → 0.00307226, 3 → 0.996928},



→ 72 312 079 279 485 910 528 → {4 → 0.00153324, 3 → 0.998467},



→ 22 158 237 683 799 083 047 → $\{4 \to 3.51784 \times 10^{-13}, 3 \to 1.\}$,

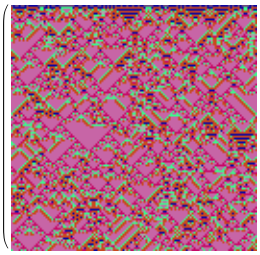


→ 142 446 781 366 136 429 283 → $\{4 \to 3.01302 \times 10^{-11}, 3 \to 1.\}\}$

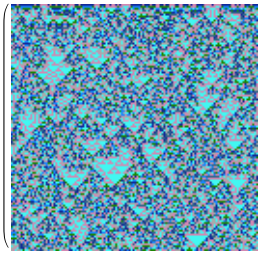
7-colour totalistic, range 1

```
In[•]:= test4Data7kr1C16 = data7TC[8, 128, 128];
        Thread[
         test4Data7kr1C16 → netECA16[Keys@test4Data7kr1C16, {"TopProbabilities", 2}]]
```

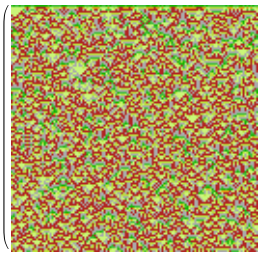
Out[•]=



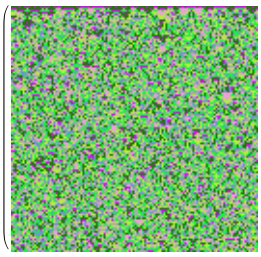
→ 3 109 608 593 887 262 → {2 → 0.0267983, 4 → 0.973202},



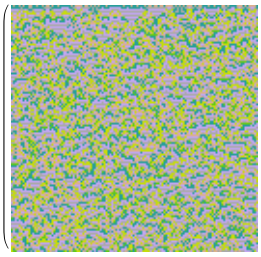
→ 10 516 337 788 191 339 → {4 → 0.202783, 3 → 0.797217},



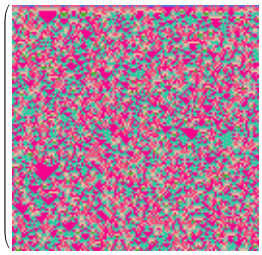
→ 10 218 434 972 470 056 → $\{4 \to 2.59313 \times 10^{-9}, 3 \to 1.\}$,

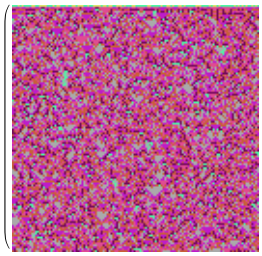


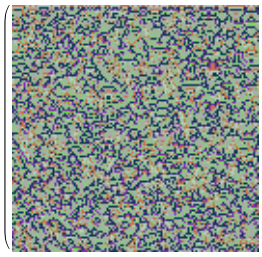
→ 11 301 098 979 433 534 → $\{4 \to 5.31247 \times 10^{-20}, 3 \to 1.\}$,



→ 4 222 218 586 098 008 → $\{4 \to 2.3505 \times 10^{-8}, 3 \to 1.\}$,

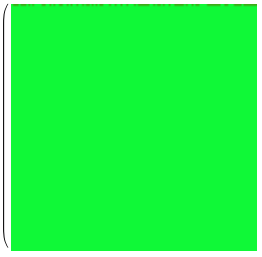

→ 6 272 918 110 265 620 → {4 → 2.82334 × 10^-12, 3 → 1.},

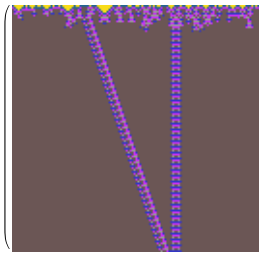

→ 7 237 960 144 206 103 → {4 → 1.82804 × 10^-11, 3 → 1.},

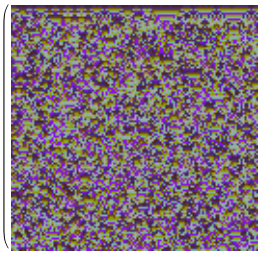

→ 8 157 411 943 012 914 → {4 → 7.30163 × 10^-8, 3 → 1.}}

In[•]:=
```
test4Data7kr1C16 = data7TC[8, 128, 128];
Thread[
 test4Data7kr1C16 → netECA16[Keys@test4Data7kr1C16, {"TopProbabilities", 2}]]
```

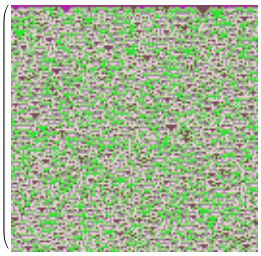
Out[•]=


{ → 2 054 187 704 193 738 → {2 → 1.00393 × 10^-7, 1 → 1.},

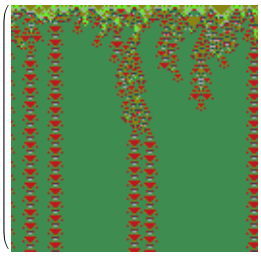

→ 4 502 314 670 347 259 → {1 → 0.000272502, 2 → 0.999727},



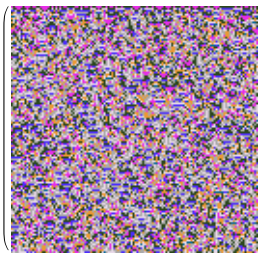
$\to 6\,433\,286\,718\,439\,853 \to \{4 \to 3.57308 \times 10^{-13}, 3 \to 1.\},$



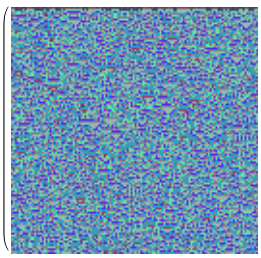
$\to 10\,115\,271\,094\,201\,812 \to \{4 \to 1.83956 \times 10^{-14}, 3 \to 1.\},$



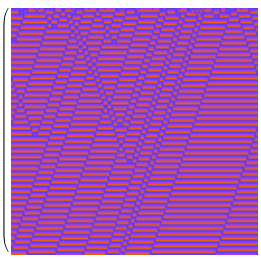
$\to 2\,056\,629\,839\,849\,700 \to \{4 \to 7.03567 \times 10^{-6}, 2 \to 0.999993\},$



$\to 6\,016\,684\,767\,156\,829 \to \{4 \to 0.0021258, 3 \to 0.997874\},$



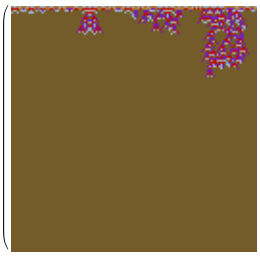
$\to 1\,150\,898\,749\,617\,983 \to \{4 \to 5.05985 \times 10^{-9}, 3 \to 1.\},$



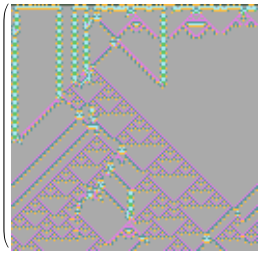
$\to 3\,441\,885\,208\,643\,463 \to \{3 \to 1.57168 \times 10^{-8}, 2 \to 1.\}\}$

In[•]:=
```
test4Data7kr1C16 = data7TC[8, 128, 128];
Thread[
 test4Data7kr1C16 → netECA16[Keys@test4Data7kr1C16, {"TopProbabilities", 2}]]
```

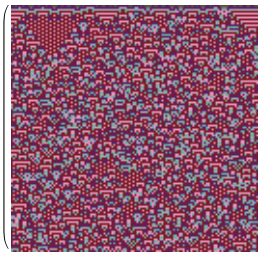
Out[•]=



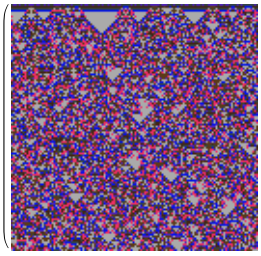
→ 8 718 538 805 570 808 → {4 → 0.0199047, 2 → 0.980095},



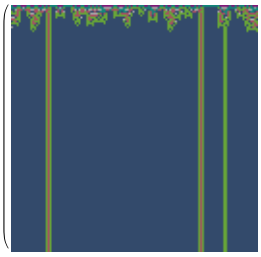
→ 5 687 458 247 703 346 → {3 → 3.931 × 10^-6, 4 → 0.999995},



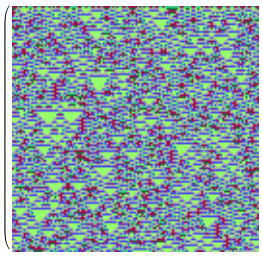
→ 2 004 300 484 518 722 → {3 → 0.0438658, 4 → 0.956134},



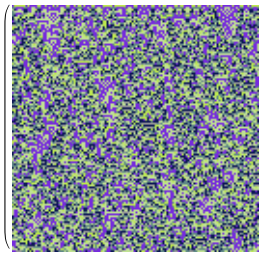
→ 2 106 485 862 858 275 → {4 → 3.36807 × 10^-10, 3 → 1.},



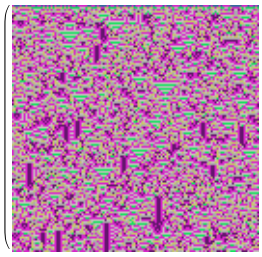
→ 10 335 102 717 390 268 → {4 → 1.40275 × 10^-9, 2 → 1.},



→ 1 948 304 137 097 478 → {4 → 3.0757 × 10^-6, 3 → 0.999997},



→ 742 855 573 082 935 → {3 → 0.00423487, 4 → 0.995765},

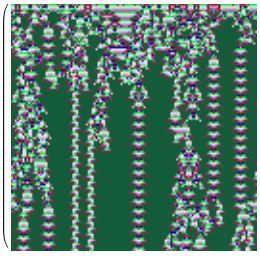


→ 550 991 988 954 034 → {3 → 0.0000158322, 4 → 0.999984}}

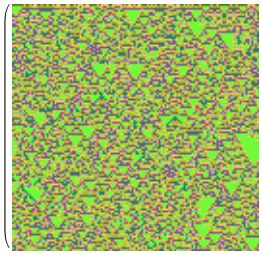
8-colour totalistic, range 1

In[•]:=
```
test4Data8kr1C16 = data8TC[8, 128, 128];
Thread[
 test4Data8kr1C16 → netECA16[Keys@test4Data8kr1C16, {"TopProbabilities", 2}]]
```

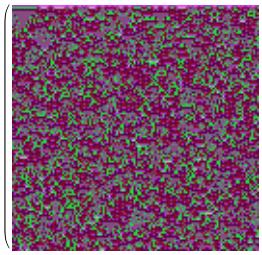
Out[•]=



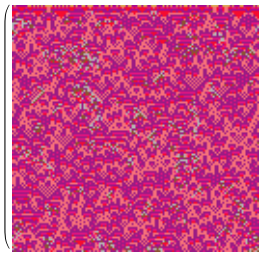
→ 26 660 220 729 300 317 631 → {3 → 4.53753 × 10^-16, 4 → 1.},



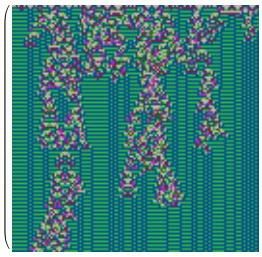
→ 57 706 619 077 455 169 987 → {4 → 0.00012086, 3 → 0.999879},



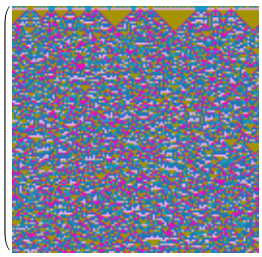
→ 64 248 301 738 433 598 883 → $\{4 \to 8.62498 \times 10^{-7}, 3 \to 0.999999\}$,



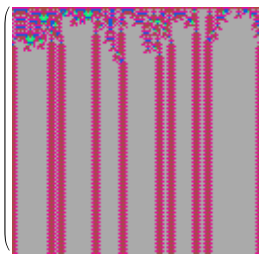
→ 38 309 191 234 358 472 181 → $\{3 \to 0.0920227, 4 \to 0.907977\}$,



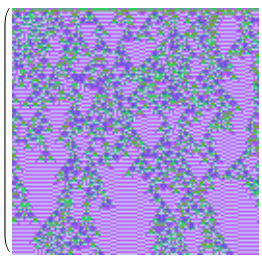
→ 10 057 418 236 647 939 786 → $\{3 \to 0.00153869, 4 \to 0.998461\}$,



→ 55 038 816 396 722 824 044 → $\{4 \to 7.93818 \times 10^{-11}, 3 \to 1.\}$,



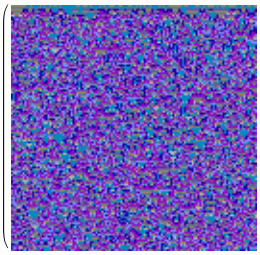
→ 13 857 790 822 319 662 750 → $\{4 \to 1.6375 \times 10^{-9}, 2 \to 1.\}$,



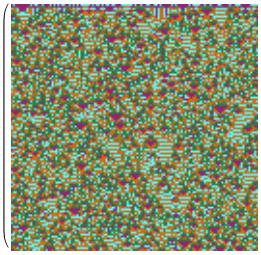
→ 35 001 739 471 058 241 746 → $\{3 \to 0.146189, 4 \to 0.853811\}\}$

```
In[•]:= test4Data8kr1C16 = data8TC[8, 128, 128];
        Thread[
         test4Data8kr1C16 → netECA16[Keys@test4Data8kr1C16, {"TopProbabilities", 2}]]
```

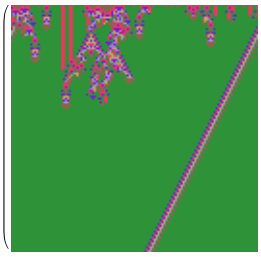
Out[•]=



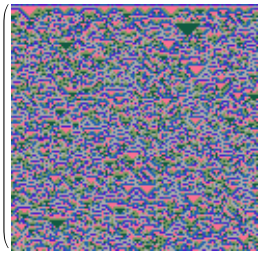
→ 8 889 571 206 431 822 669 → {4 → 7.71651 × 10^-13, 3 → 1.},



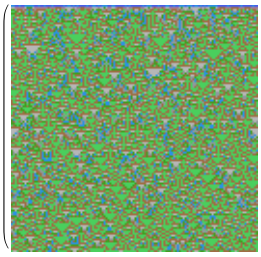
→ 12 932 107 158 159 577 869 → {4 → 0.000487127, 3 → 0.999513},



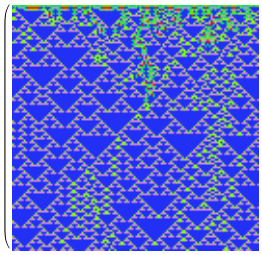
→ 38 300 014 541 797 689 408 → {2 → 4.40131 × 10^-9, 4 → 1.},



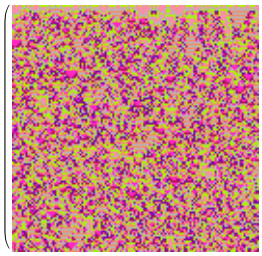
→ 73 619 662 786 582 031 542 → {4 → 2.6954 × 10^-22, 3 → 1.},



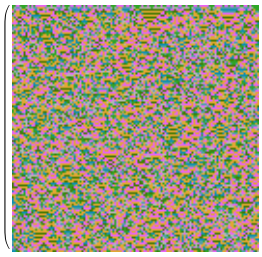
→ 25 075 664 454 379 326 631 → {4 → 2.7484 × 10^-6, 3 → 0.999997},



→ 66 251 301 754 800 867 134 → {4 → 0.045885, 3 → 0.954115},



→ 45 939 929 171 629 412 480 → {3 → 0.0015837, 4 → 0.998416},



→ 48 918 067 825 593 479 863 → {4 → 0.000601606, 3 → 0.999398}

Network XVII - Four convolutions, dropout on linear only, BatchNorm

In[ ]:= **netECA17 = netTenCC1024drop[128, 128]**

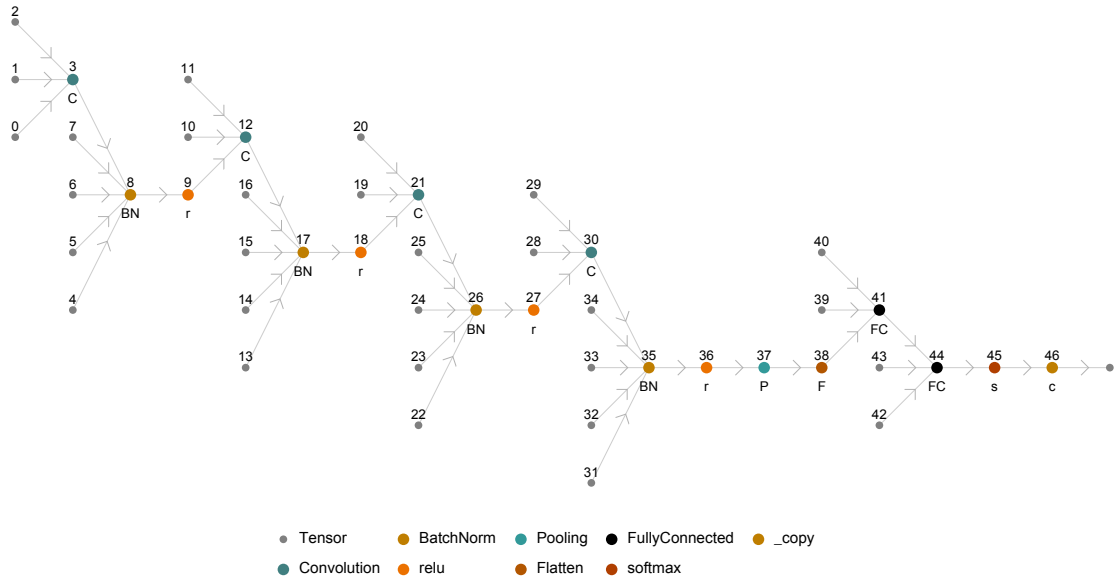
Out[ ]= NetChain[

	Input	image array (size: 3 × 128 × 128)
conv1	ConvolutionLayer	array (size: 24 × 126 × 126)
bat1	BatchNormalizationLayer	array (size: 24 × 126 × 126)
ramp1	Ramp	array (size: 24 × 126 × 126)
conv2	ConvolutionLayer	array (size: 24 × 124 × 124)
bat2	BatchNormalizationLayer	array (size: 24 × 124 × 124)
ramp2	Ramp	array (size: 24 × 124 × 124)
conv3	ConvolutionLayer	array (size: 24 × 122 × 122)
bat3	BatchNormalizationLayer	array (size: 24 × 122 × 122)
ramp3	Ramp	array (size: 24 × 122 × 122)
conv4	ConvolutionLayer	array (size: 24 × 120 × 120)
bat4	BatchNormalizationLayer	array (size: 24 × 120 × 120)
ramp4	Ramp	array (size: 24 × 120 × 120)
pooling	PoolingLayer	array (size: 24 × 5 × 5)
flatten	FlattenLayer	vector (size: 600)
linear	LinearLayer	vector (size: 1024)
drop2	DropoutLayer	vector (size: 1024)
linear2	LinearLayer	vector (size: 4)
softmax	SoftmaxLayer	vector (size: 4)
	Output	class

]

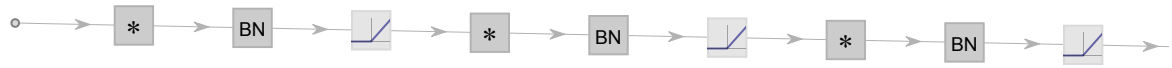
In[•]:=
```
NetInformation[netECA17, "MXNetNodeGraphPlot"]
```

Out[•]=



In[•]:=
```
NetInformation[netECA17, "SummaryGraphic"]
```

Out[•]=



In[•]:=
```
dataECA17 = dataC[128, 128, 16 384];
```

In[•]:=
```
dataTotalistic2BigC17 = genData2r2C[128, 128, 2048];
```

In[•]:=
```
dataTotalistic3BigC17 = data3T2C[128, 128, 2048];
```

In[•]:=
```
dataTotalistic4BigC17 = data4TC[128, 128, 2048];
```

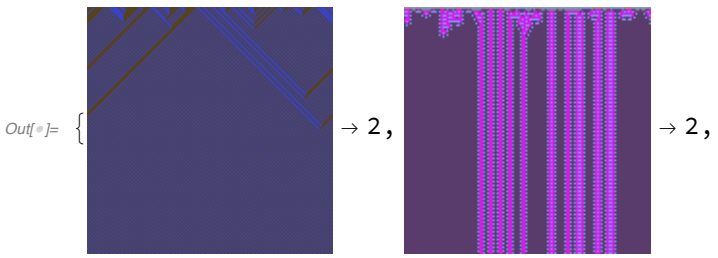
In[•]:=
```
dataTotalistic5BigC17 = genData5TCC[128, 128, 8192];
```

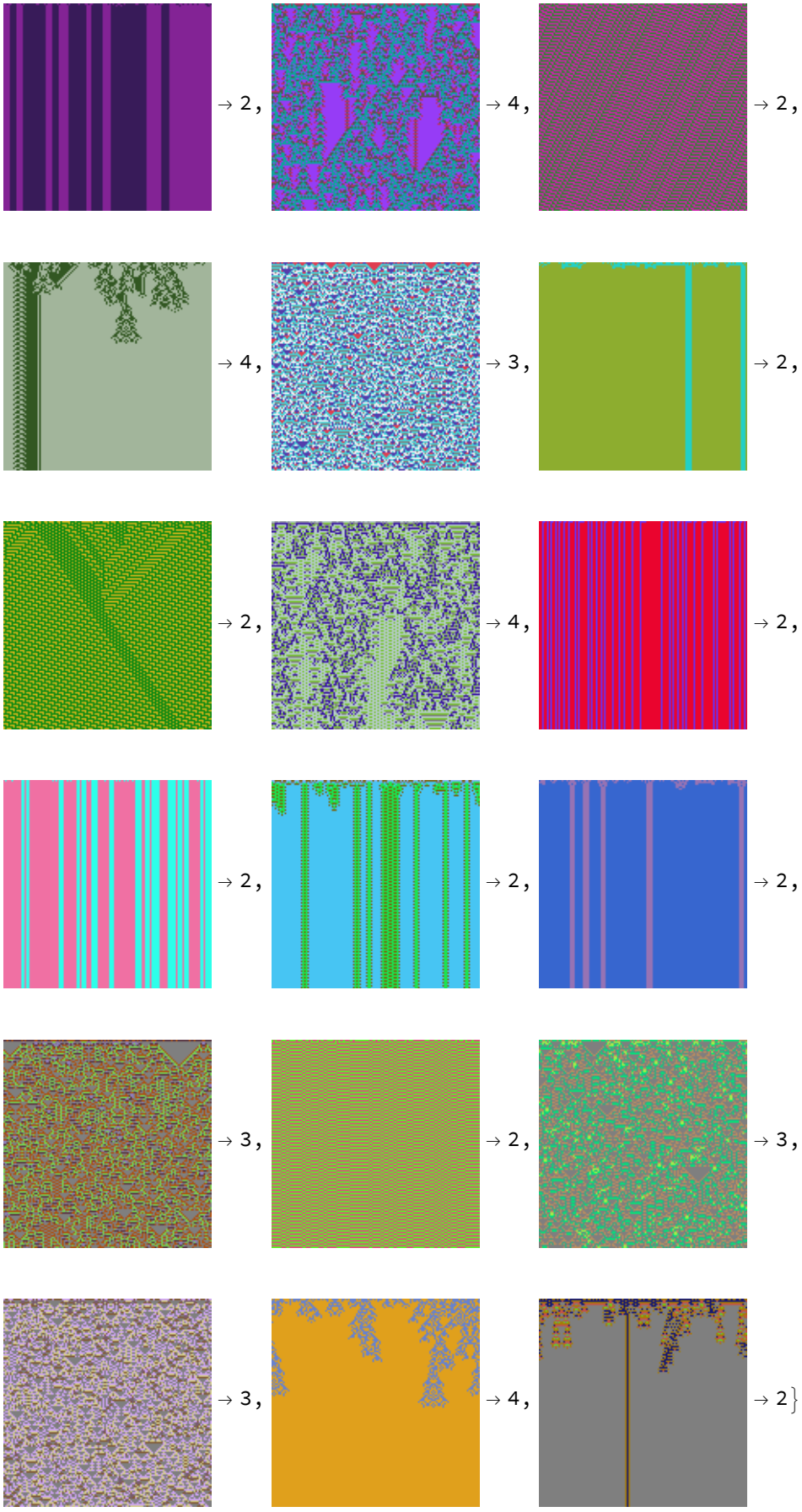
In[•]:=
```
fullTrainingBigC17 = Join[dataECA17, dataTotalistic2BigC17,
   dataTotalistic3BigC17, dataTotalistic4BigC17, dataTotalistic5BigC17];
Length[fullTrainingBigC17]
```

Out[•]=
```
53 248
```

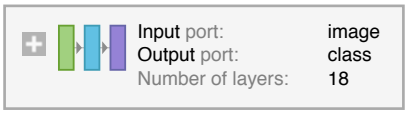
In[•]:=
```
RandomSample[fullTrainingBigC17, 20]
```

Out[•]=




→ 2,
→ 4,
→ 2,
→ 4,
→ 3,
→ 2,
→ 2,
→ 4,
→ 2,
→ 2,
→ 2,
→ 2,
→ 3,
→ 2,
→ 3,
→ 3,
→ 4,
→ 2}

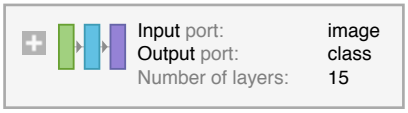
```
In[•]:= dir = SetDirectory[NotebookDirectory[]]
In[•]:= "/home/esilverman/Documents"
Out[•]= /home/esilverman/Documents

In[•]:= netECA17 = NetTrain[netECA17, fullTrainingBigC17,
          MaxTrainingRounds → 200, BatchSize → 256, TargetDevice → "GPU",
          TrainingProgressCheckpointing → {"Directory", dir}]
```

Out[•]= NetChain[]


```
netECA17 = Import["netECA17-r200.wlnet"]
```

Generate test data for Network XVII (200 epochs)

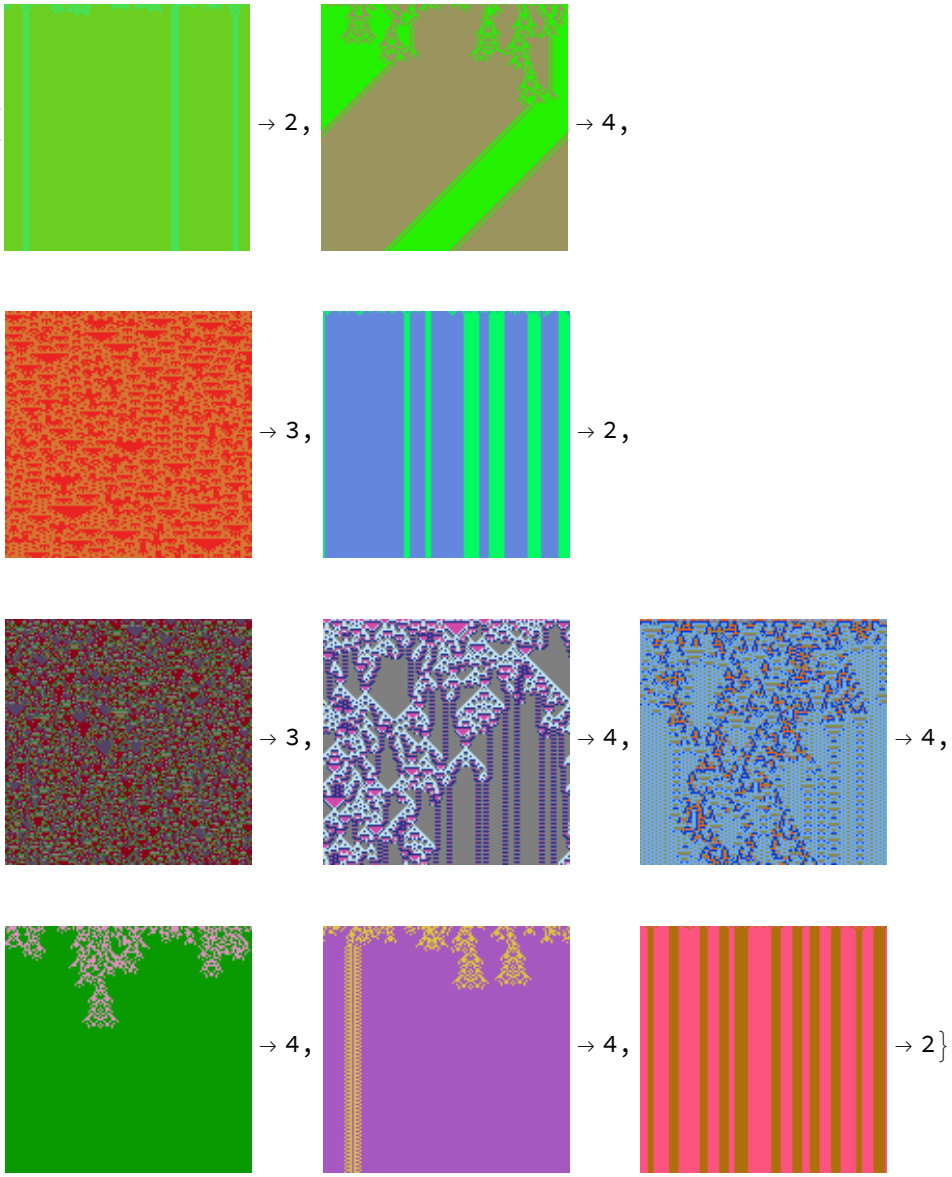
```
In[•]:= dir = SetDirectory[NotebookDirectory[]]
Out[•]= /Users/thorsilver/Downloads/Wolfram notebooks

netECA17 = Import["netECA17-r200.wlnet"]
```

Out[•]= NetChain[]


```
In[•]:= testDataECABigC = dataC[128, 128, 1024];
        testData2TBigC = genData2r2C[128, 128, 1024];
        testData3TBigC = data3T2C[128, 128, 1024];
        testData4TBigC = data4TC[128, 128, 1024];
        testData5TBigC = genData5TCC[128, 128, 1024];
        fullTestSetBigC = Join[testDataECABigC,
           testData2TBigC, testData3TBigC, testData4TBigC, testData5TBigC];
        Length[fullTestSetBigC]
Out[•]= 10 240
```

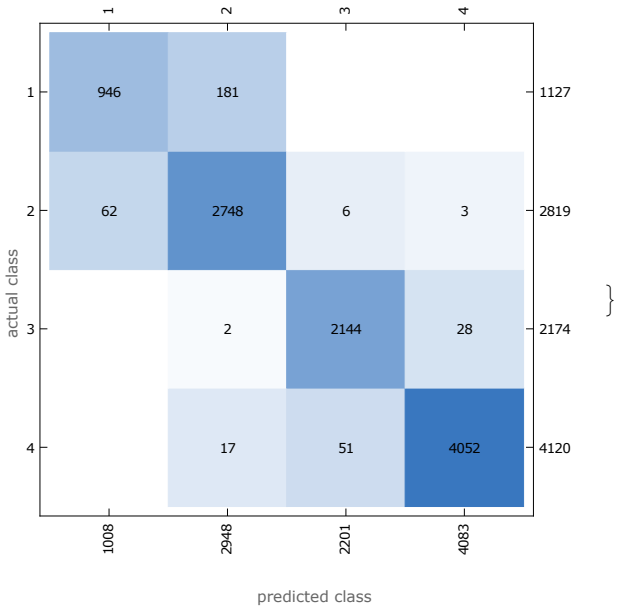
In[•]:= `RandomSample[fullTestSetBigC, 10]`

Out[•]=

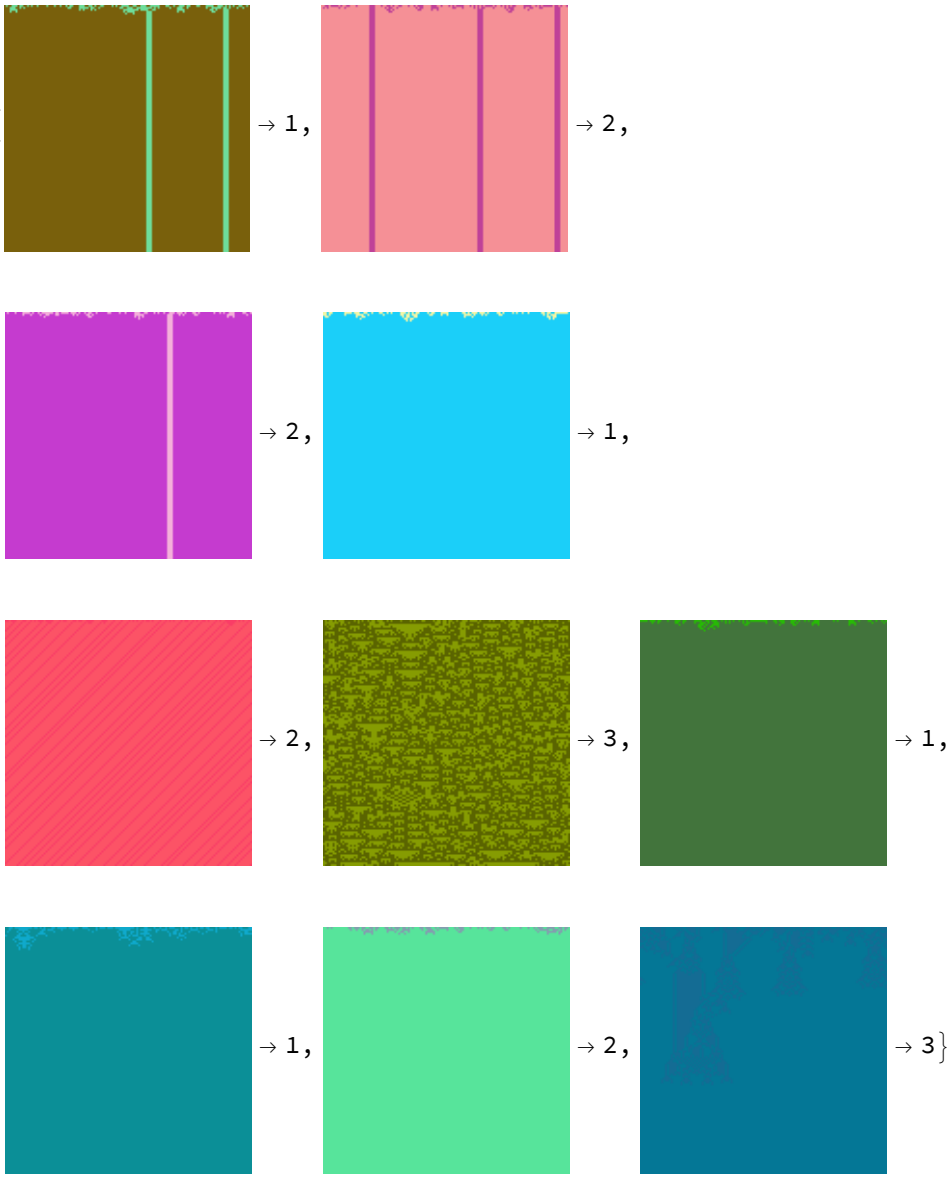


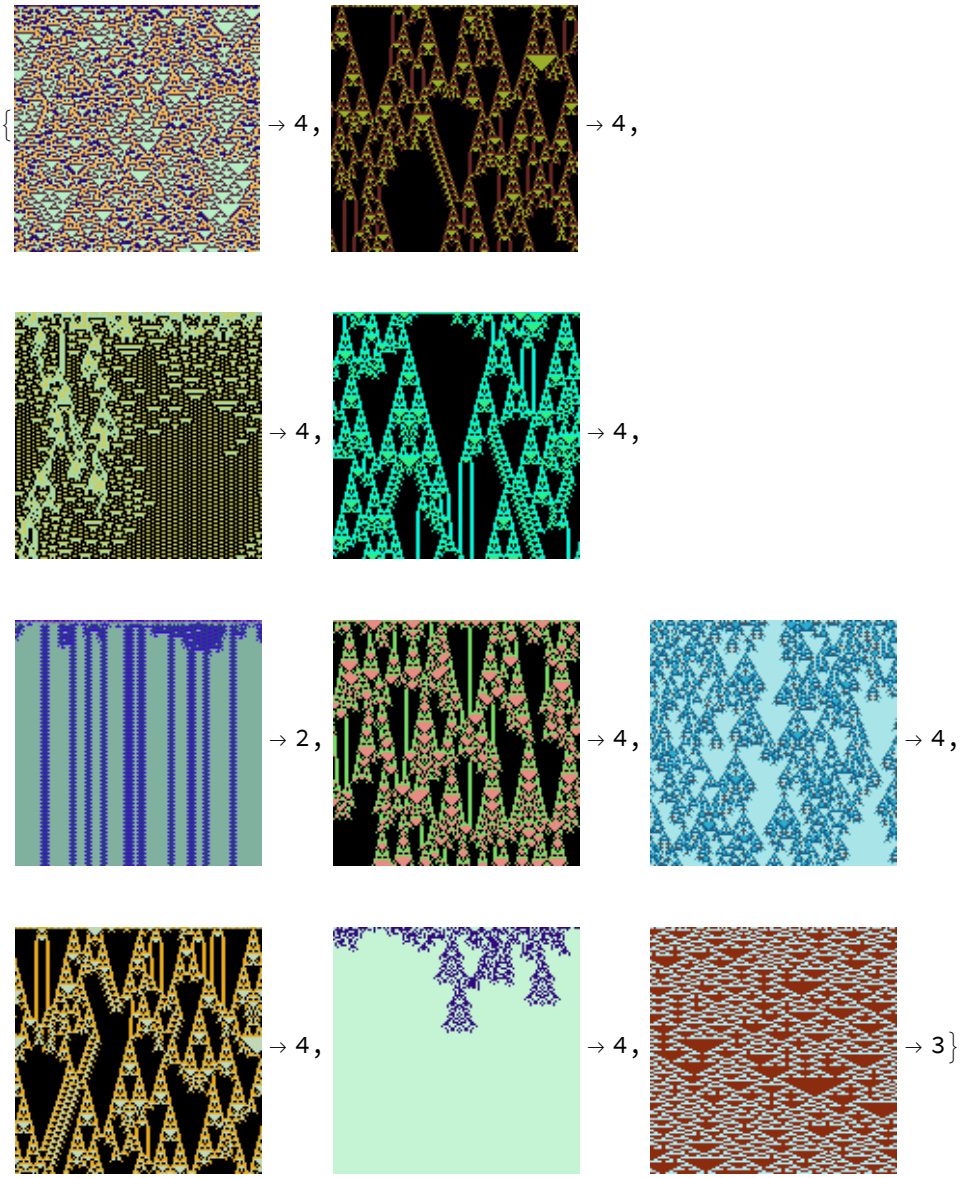
In[]:=
```
NetMeasurements[netECA17, fullTestSetBigC,
 {"Accuracy", "Precision", "ConfusionMatrixPlot"}]
```

Out[]=
```
{0.96582, ⟨|1 → 0.938492, 2 → 0.932157, 3 → 0.974103, 4 → 0.992408|⟩,
```



In[]:=
```
entropyImagesBigC = RandomSample[Keys[fullTestSetBigC], 500];
entropiesBigC = netECA17[entropyImagesBigC, "Entropy"];
highEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, -10]]];
lowEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, 10]]];
Thread[highEntBigC → netECA17[highEntBigC]]
Thread[lowEntBigC → netECA17[lowEntBigC]]
```

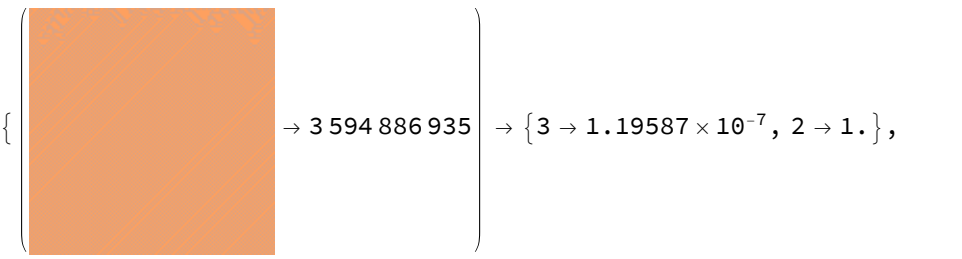
Out[•]= 

Out[•]= 

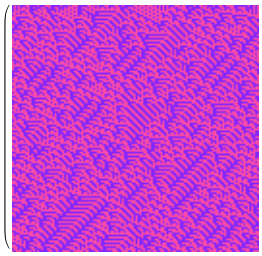
Testing Network XVII (200 epochs) on unseen CA rule spaces

2-colour non-totalistic, range 2

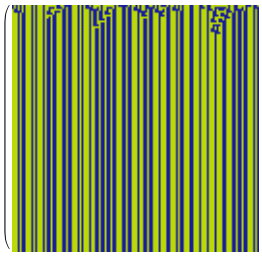
In[•]:=
```
test4Data2kr2C17 = datak2r2C[128, 128, 8];
Thread[
 test4Data2kr2C17 → netECA17[Keys@test4Data2kr2C17, {"TopProbabilities", 2}]]
```

Out[•]= 

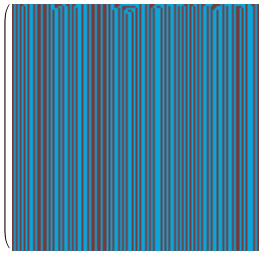
→ 4 012 014 789 → {4 → 0.00317589, 3 → 0.996824},



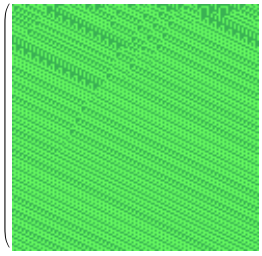
→ 736 342 145 → {4 → 0.000138652, 3 → 0.999861},



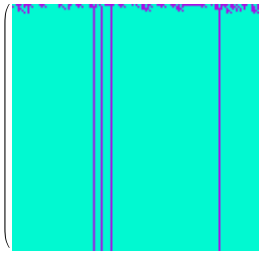
→ 3 597 938 931 → $\{4 \to 5.42024 \times 10^{-16}, 2 \to 1.\}$,



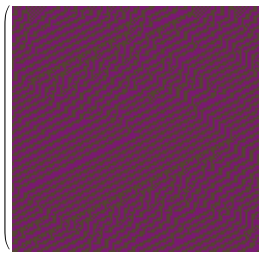
→ 49 406 137 → $\{1 \to 4.03179 \times 10^{-30}, 2 \to 1.\}$,



→ 669 500 034 → {4 → 0.0129747, 2 → 0.983657},



→ 4 122 605 661 → $\{1 \to 6.18382 \times 10^{-9}, 2 \to 1.\}$,

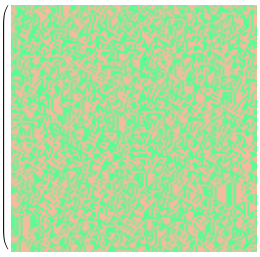


→ 2 751 618 302 → {4 → 5.91412 × 10^-9, 3 → 1.}}

2-colour non-totalistic, range 3

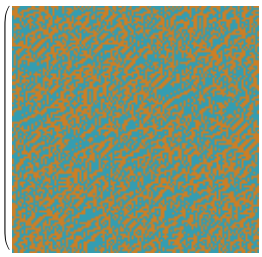
In[•]:=
```
test4Data2kr3C17 = datak2r3NT[128, 128, 8];
Thread[
 test4Data2kr3C17 → netECA17[Keys@test4Data2kr3C17, {"TopProbabilities", 2}]]
```

Out[•]=

{ 

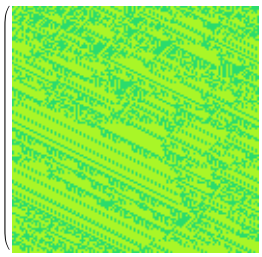
→ 34 540 309 799 423 528 179 267 302 306 223 835 543 →

{4 → 0.0000190167, 3 → 0.999981},



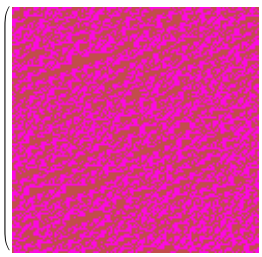
→ 271 913 994 962 168 934 532 188 611 494 783 284 369 →

{4 → 8.79258 × 10^-15, 3 → 1.},



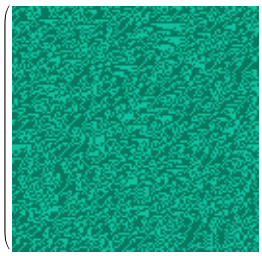
→ 328 899 203 265 424 040 719 063 648 351 222 904 052 →

{3 → 0.000609094, 4 → 0.999391},



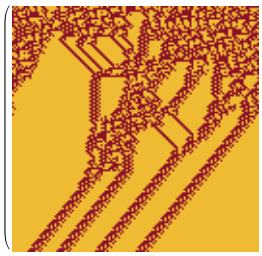
→ 193 952 196 319 600 964 880 345 641 761 505 849 023 →

$\{4 \to 8.96571 \times 10^{-10}, 3 \to 1.\}$,



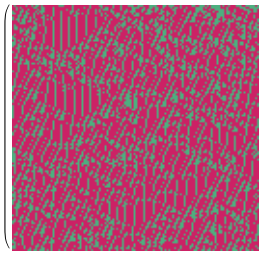
→ 196 656 308 173 162 097 107 061 836 715 379 270 739 →

$\{4 \to 3.36397 \times 10^{-6}, 3 \to 0.999997\}$,



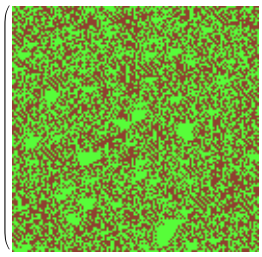
→ 26 038 517 878 084 050 104 120 010 197 636 533 172 →

$\{3 \to 5.4757 \times 10^{-7}, 4 \to 0.999999\}$,



→ 252 109 815 601 340 225 609 723 212 759 419 626 786 →

$\{4 \to 1.35911 \times 10^{-8}, 3 \to 1.\}$,



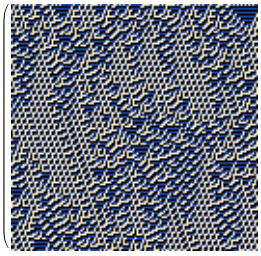
→ 306 252 930 975 464 521 922 673 887 271 988 404 115 →

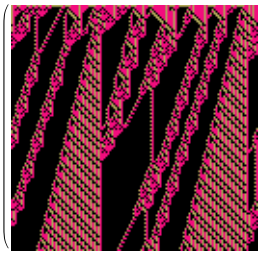
$\{4 \to 5.68649 \times 10^{-7}, 3 \to 0.999999\}\}$

3-colour non-totalistic, range 1

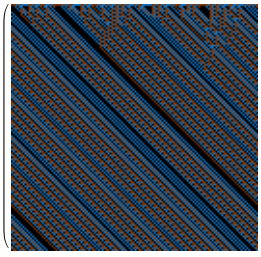
In[•]:=
```
test4Data3kr1C17 = datak3r1NT[128, 128, 8];
Thread[
 test4Data3kr1C17 → netECA17[Keys@test4Data3kr1C17, {"TopProbabilities", 2}]]
```

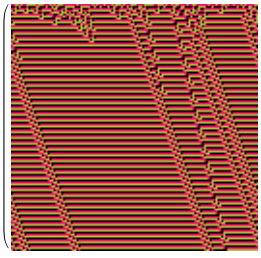
Out[•]= {  → 1 924 646 489 567 → {3 → 1.76606 × 10^-30, 2 → 1.},

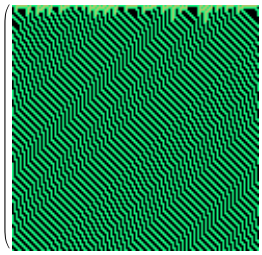
 → 3 672 534 501 071 → {2 → 0.0000110699, 4 → 0.999989},

 → 5 833 330 297 781 → {2 → 0.000232935, 4 → 0.999767},

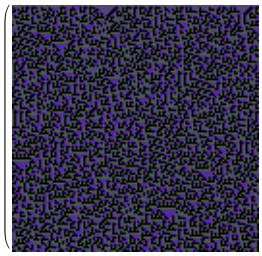
 → 7 606 192 973 798 → {2 → 6.802 × 10^-10, 1 → 1.},

 → 7 622 301 560 954 → {3 → 0.0391643, 2 → 0.960836},

 → 3 685 910 174 297 → {3 → 2.7602 × 10^-8, 4 → 1.},



→ 5 743 838 876 456 → {1 → 6.15406 × 10^-23, 2 → 1.},

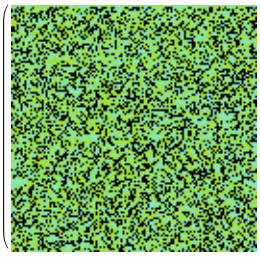


→ 3 655 040 152 191 → {4 → 0.0374305, 3 → 0.962569}}

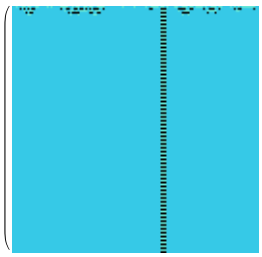
3-colour totalistic, range 2

In[•]:=
```
test4Data3kr2C17 = datak3r2C[128, 128, 8];
Thread[
 test4Data3kr2C17 → netECA17[Keys@test4Data3kr2C17, {"TopProbabilities", 2}]]
```

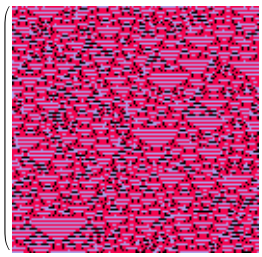
Out[•]=



→ 43 149 → {4 → 1.6989 × 10^-8, 3 → 1.},



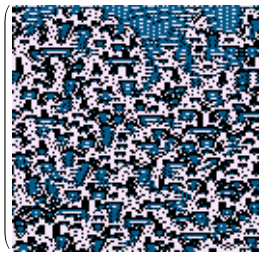
→ 160 434 → {1 → 2.05354 × 10^-18, 2 → 1.},



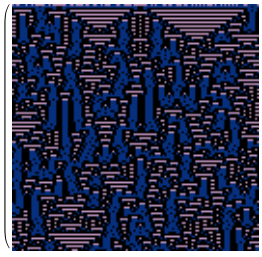
→ 9535 → {3 → 0.0000598239, 4 → 0.99994},

→ 172 239 → {1 → 0.00705153, 2 → 0.992948},

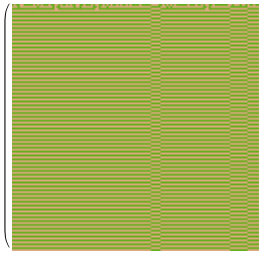
→ 174 680 → {2 → 5.824 × 10^-11, 1 → 1.},



→ 55 945 → {4 → 0.0138349, 3 → 0.986165},



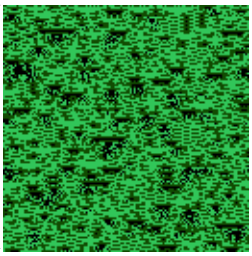
→ 113 483 → {4 → 3.72822 × 10^-6, 3 → 0.999996},

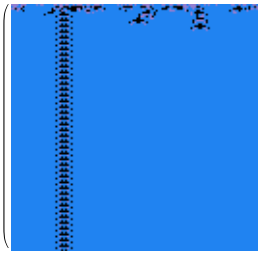


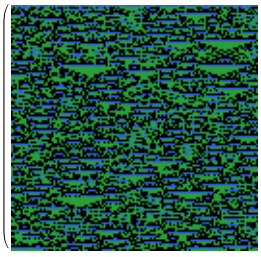
→ 67 810 → {1 → 6.91386 × 10^-17, 2 → 1.}}

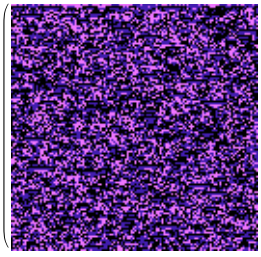
3-colour totalistic, range 3

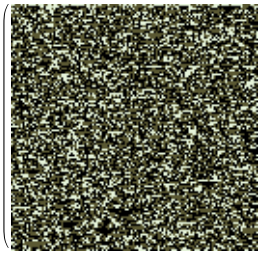
In[•]:=
```
test4Data3kr3C17 = datak3r3C[128, 128, 8];
Thread[
 test4Data3kr3C17 → netECA17[Keys@test4Data3kr3C17, {"TopProbabilities", 2}]]
```

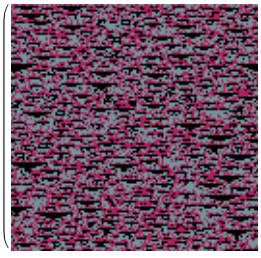
Out[•]= {  → 3 046 610 → {4 → 7.58312 × 10^-7, 3 → 0.999999},

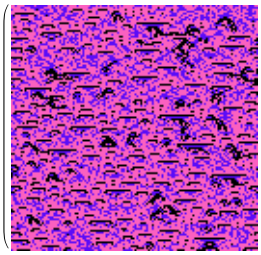
 → 7 801 434 → {1 → 1.19167 × 10^-14, 2 → 1.},

 → 5 445 843 → {4 → 1.60992 × 10^-19, 3 → 1.},

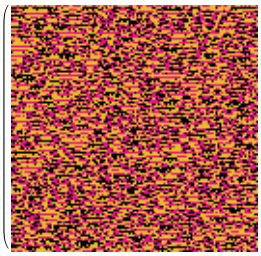
 → 1 451 413 → {4 → 0.144413, 3 → 0.855587},

 → 10 676 790 → {3 → 0.0738921, 4 → 0.926108},

 → 10 375 449 → {4 → 1.04031 × 10^-17, 3 → 1.},



→ 5 181 761 → {4 → 1.75908 × 10^-8, 3 → 1.}

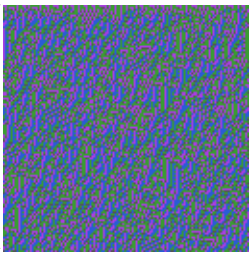


→ 8 884 285 → {4 → 7.91486 × 10^-6, 3 → 0.999992}}

4-colour non-totalistic, range 1

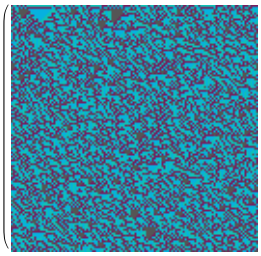
In[•]:=
```
test4Data4kr1C17 = datak4r1NT[128, 128, 8];
Thread[
 test4Data4kr1C17 → netECA17[Keys@test4Data4kr1C17, {"TopProbabilities", 2}]]
```

Out[•]=

{ 

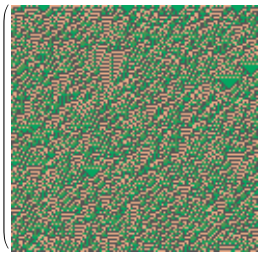
→ 255 219 118 556 246 495 764 448 982 135 818 252 673 →

{3 → 2.62807 × 10^-6, 4 → 0.999997},



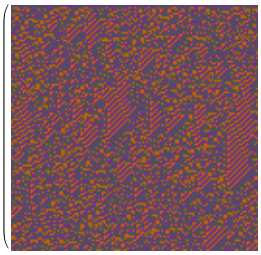
→ 256 372 744 774 750 994 462 308 116 064 689 670 029 →

{4 → 1.66442 × 10^-17, 3 → 1.},



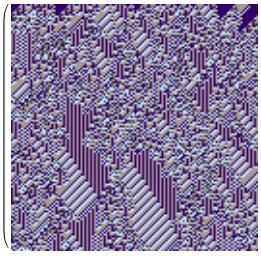
→ 287 015 413 736 003 568 798 718 608 141 279 906 438 →

$\{4 \to 2.56385 \times 10^{-7}, 3 \to 1.\},$



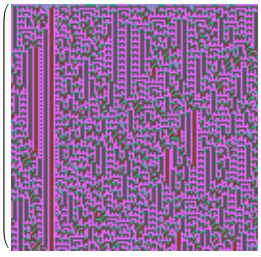
$\to 102\,047\,809\,483\,228\,794\,436\,919\,245\,364\,544\,665\,433 \to$

$\{4 \to 0.000696463, 3 \to 0.999304\},$



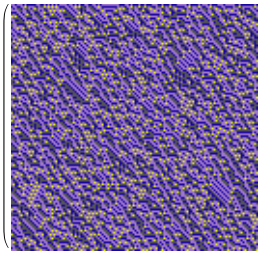
$\to 240\,555\,046\,861\,732\,528\,519\,285\,194\,385\,835\,154\,772 \to$

$\{4 \to 3.62136 \times 10^{-16}, 3 \to 1.\},$



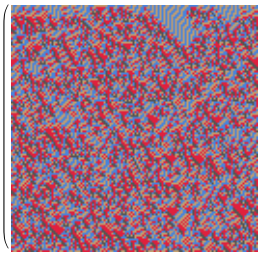
$\to 16\,370\,468\,900\,338\,540\,956\,022\,703\,184\,589\,781\,262 \to$

$\{3 \to 1.45252 \times 10^{-15}, 4 \to 1.\},$



$\to 121\,099\,422\,536\,966\,135\,180\,998\,722\,819\,969\,755\,137 \to$

$\{4 \to 0.0000270873, 3 \to 0.999973\},$



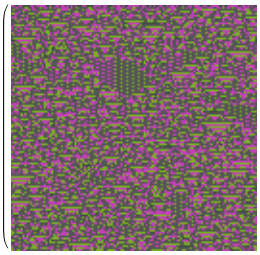
$\to 264\,867\,193\,286\,423\,906\,380\,401\,526\,070\,744\,380\,919 \to$

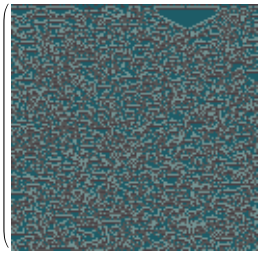
$\{4 \to 0.105214, 3 \to 0.894786\}\}$

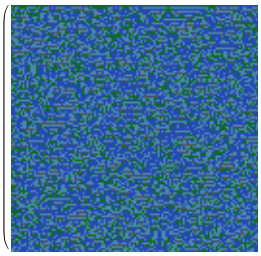
4-colour totalistic, range 2

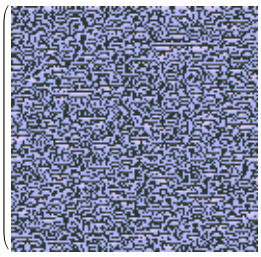
In[•]:=
```
test4Data4kr2C17 = datak4r2C[128, 128, 8];
Thread[
 test4Data4kr2C17 → netECA17[Keys@test4Data4kr2C17, {"TopProbabilities", 2}]]
```

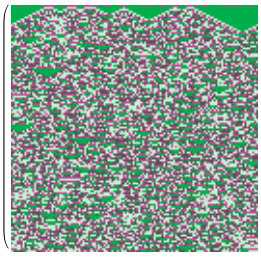
Out[•]=

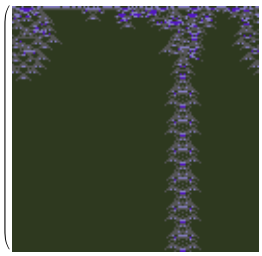

→ 616 082 315 → {4 → 8.8653 × 10^-10, 3 → 1.},


→ 1 568 191 428 → {4 → 5.21264 × 10^-11, 3 → 1.},

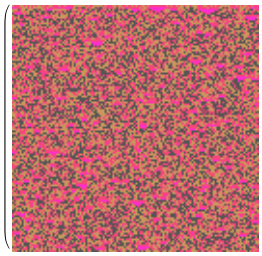

→ 1 216 110 065 → {4 → 0.000040346, 3 → 0.99996},


→ 2 419 903 949 → {4 → 3.69897 × 10^-10, 3 → 1.},

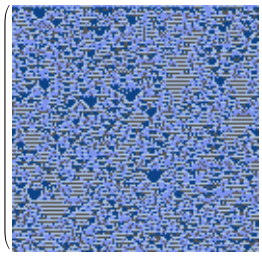

→ 453 961 055 → {4 → 3.89961 × 10^-8, 3 → 1.},



→ 3 969 029 930 → {2 → 0.0000237283, 4 → 0.999976},



→ 3 970 208 335 → {4 → 4.03487 × 10^-9, 3 → 1.},

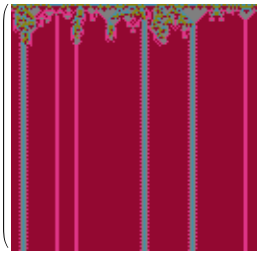


→ 3 418 384 250 → {4 → 9.0126 × 10^-15, 3 → 1.}}

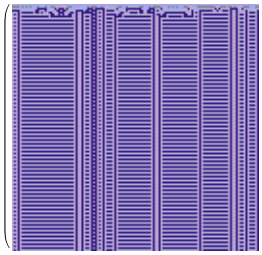
5-colour totalistic, range 1

In[•]:=
```
test4Data5kr1C17 = data5T2C[8, 128, 128];
Thread[
 test4Data5kr1C17 → netECA17[Keys@test4Data5kr1C17, {"TopProbabilities", 2}]]
```

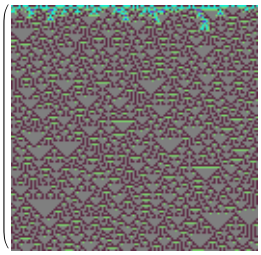
Out[•]=



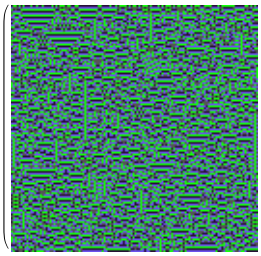
{ → 720 503 516 → {2 → 0.000105936, 4 → 0.999894},



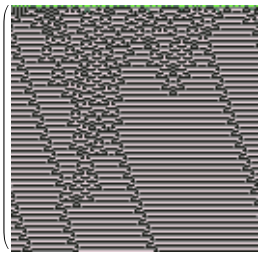
→ 771 013 684 → {4 → 1.94282 × 10^-8, 2 → 1.},



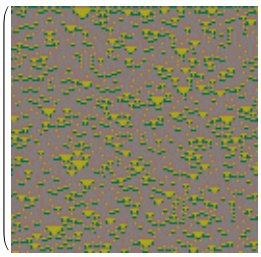
$\to 543\,872\,434 \Big| \to \left\{4 \to 6.11423 \times 10^{-7}, 3 \to 0.999999\right\},$



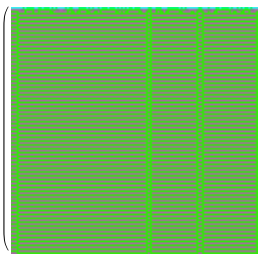
$\to 341\,908\,586 \Big| \to \{4 \to 0.310854, 3 \to 0.689146\},$



$\to 664\,036\,861 \Big| \to \{2 \to 0.00511847, 4 \to 0.994882\},$



$\to 1\,182\,110\,899 \Big| \to \{4 \to 0.039023, 3 \to 0.960977\},$



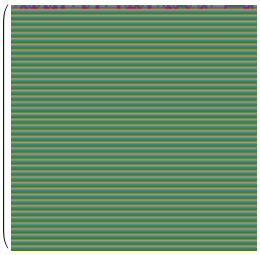
$\to 976\,082\,949 \Big| \to \left\{4 \to 9.09593 \times 10^{-19}, 2 \to 1.\right\},$

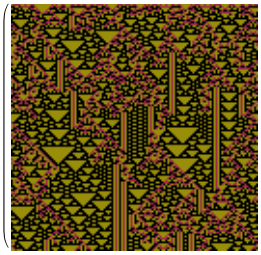
$\to 1\,019\,517\,181 \Big| \to \left\{1 \to 6.47917 \times 10^{-10}, 2 \to 1.\right\}\}$

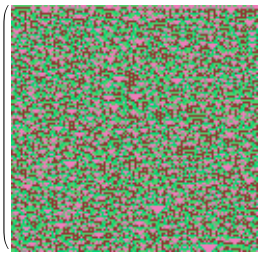
6-colour totalistic, range 1

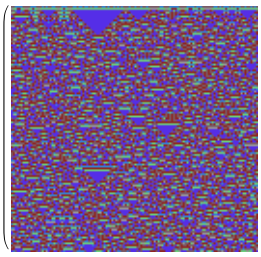
In[•]:=
```
test4Data6kr1C17 = data6TC[8, 128, 128];
Thread[
 test4Data6kr1C17 → netECA17[Keys@test4Data6kr1C17, {"TopProbabilities", 2}]]
```

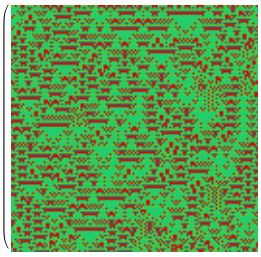
Out[•]=

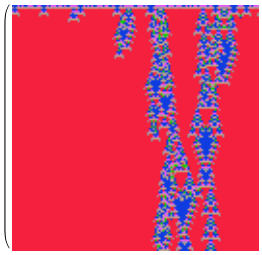

→ 1 128 957 409 115 → {2 → 0.387573, 1 → 0.612427},


→ 744 151 919 694 → $\{3 \to 1.28454 \times 10^{-11}, 4 \to 1.\}$,

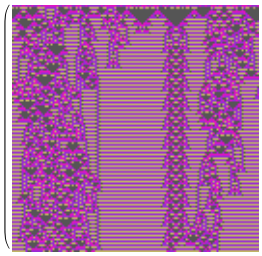

→ 411 482 269 593 → $\{4 \to 9.50671 \times 10^{-6}, 3 \to 0.99999\}$,


→ 2 122 826 252 429 → $\{4 \to 4.58698 \times 10^{-10}, 3 \to 1.\}$,

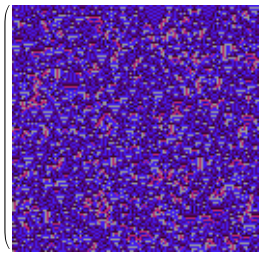

→ 2 443 710 325 124 → $\{4 \to 5.97811 \times 10^{-9}, 3 \to 1.\}$,



→ 2 519 595 515 832 → {2 → 0.396179, 4 → 0.603821},



→ 572 558 234 379 → $\{4 \to 1.63969 \times 10^{-11}, 3 \to 1.\}$,

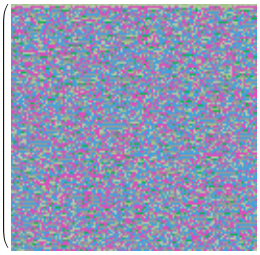


→ 2 103 617 145 248 → $\{3 \to 8.41391 \times 10^{-9}, 4 \to 1.\}\}$

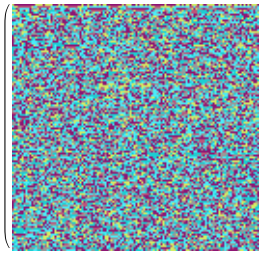
6-colour totalistic, range 2

In[•]:=
```
test4Data6kr2C17 = data6T2C[8, 128, 128];
Thread[
 test4Data6kr2C17 → netECA17[Keys@test4Data6kr2C17, {"TopProbabilities", 2}]]
```

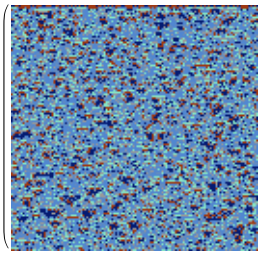
Out[•]=



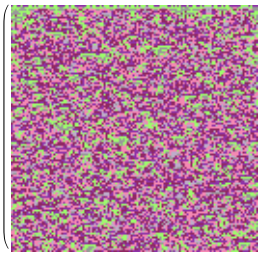
→ 56 518 611 906 036 513 420 → {4 → 0.00132297, 3 → 0.998677},



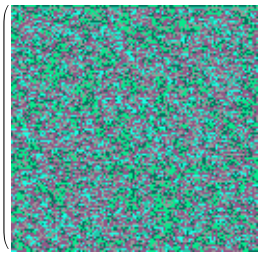
→ 149 111 145 742 470 978 404 → {4 → 0.00110016, 3 → 0.9989},



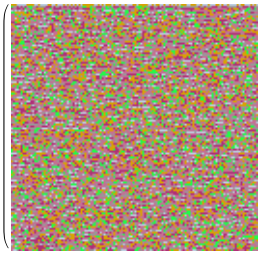
→ 60 075 298 400 874 491 559 → {4 → 0.0000816385, 3 → 0.999918},



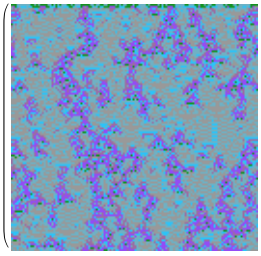
→ 61 137 219 885 741 406 688 → {4 → 6.01526 × 10^-9, 3 → 1.},



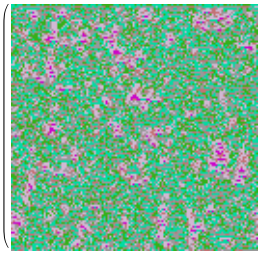
→ 138 083 937 800 052 503 915 → {4 → 1.63338 × 10^-6, 3 → 0.999998},



→ 102 848 890 668 267 918 696 → {4 → 4.51684 × 10^-8, 3 → 1.},



→ 52 002 759 529 482 240 344 → {4 → 0.0161382, 3 → 0.983862},

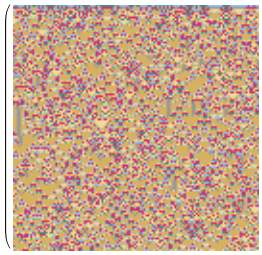


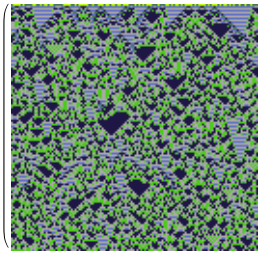
→ 3 771 326 190 903 203 597 → {4 → 1.57635 × 10^-10, 3 → 1.}}

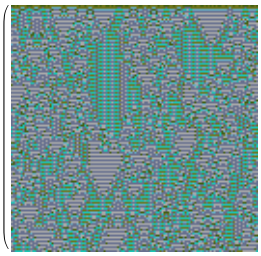
7-colour totalistic, range 1

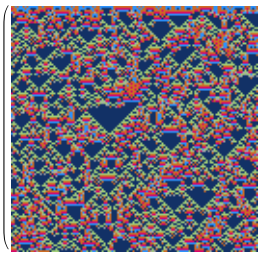
In[•]:=
```
test4Data7kr1C17 = data7TC[8, 128, 128];
Thread[
 test4Data7kr1C17 → netECA17[Keys@test4Data7kr1C17, {"TopProbabilities", 2}]]
```

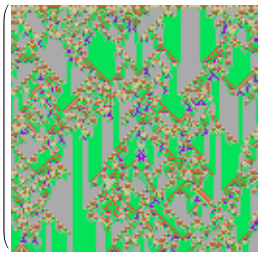
Out[•]=

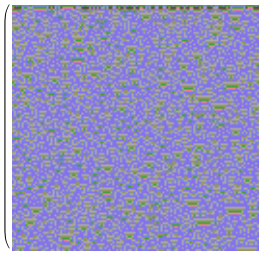

→ 249 739 897 876 317 → {4 → 7.58753 × 10^-13, 3 → 1.},


→ 6 589 873 174 284 234 → {4 → 3.70203 × 10^-21, 3 → 1.},

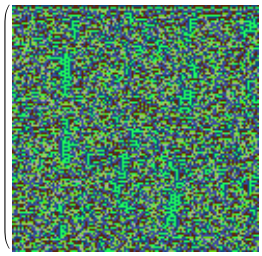

→ 2 838 251 451 633 386 → {3 → 0.0000362001, 4 → 0.999964},


→ 3 069 021 856 393 877 → {4 → 4.6982 × 10^-6, 3 → 0.999995},

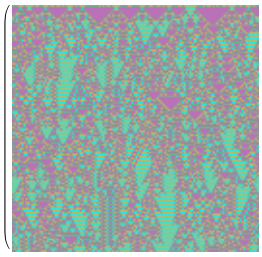

→ 10 282 712 720 317 214 → {3 → 4.14045 × 10^-19, 4 → 1.},



→ 203 015 413 423 084 → {4 → 2.87431 × 10^-9, 3 → 1.},



→ 9 746 864 148 555 591 → {3 → 1.53822 × 10^-7, 4 → 1.},

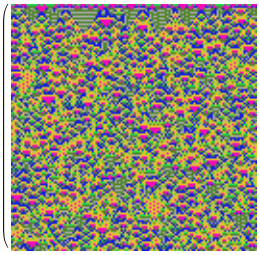


→ 8 003 062 538 664 128 → {3 → 2.05185 × 10^-8, 4 → 1.}}

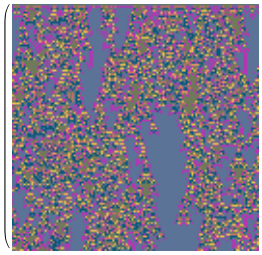
8-colour totalistic, range 1

In[•]:=
```
test4Data8kr1C17 = data8TC[8, 128, 128];
Thread[
 test4Data8kr1C17 → netECA17[Keys@test4Data8kr1C17, {"TopProbabilities", 2}]]
```

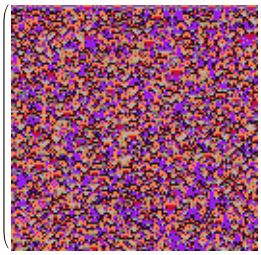
Out[•]=



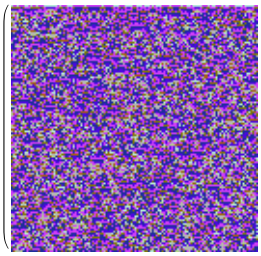
{→ 10 266 196 594 935 096 075 → {4 → 8.5791 × 10^-18, 3 → 1.},



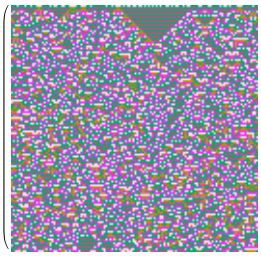
→ 731 338 973 990 773 560 → {2 → 7.53019 × 10^-12, 4 → 1.},



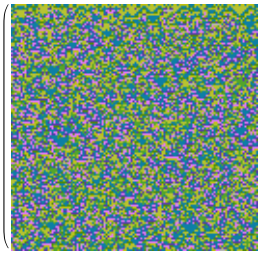
→ 11 247 173 012 174 218 620 → {4 → 0.0000380778, 3 → 0.999962},



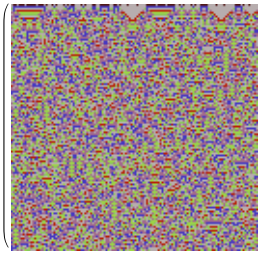
→ 63 742 472 032 617 219 918 → {4 → 0.0000371126, 3 → 0.999963},



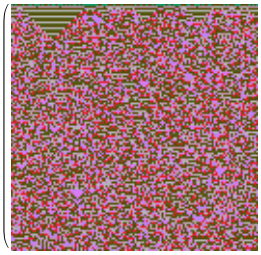
→ 7 382 455 380 800 363 015 → $\{4 \to 8.07468 \times 10^{-15}, 3 \to 1.\}$,



→ 59 100 651 667 569 734 000 → $\{4 \to 1.27228 \times 10^{-11}, 3 \to 1.\}$,



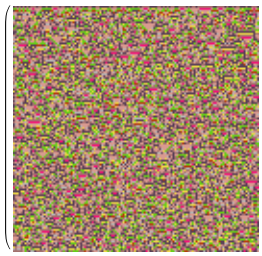
→ 24 971 306 247 396 766 335 → {4 → 0.0333734, 3 → 0.966627},

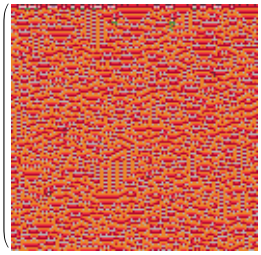


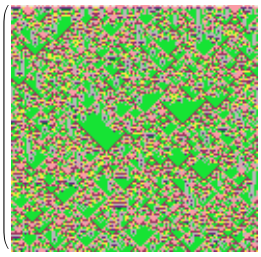
→ 45 946 581 080 593 555 746 → $\{4 \to 1.08598 \times 10^{-15}, 3 \to 1.\}\}$

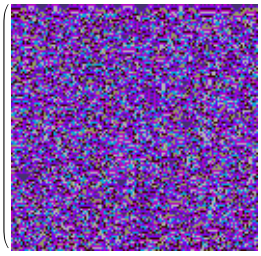
In[•]:=
```
test4Data8kr1C17 = data8TC[8, 128, 128];
Thread[
 test4Data8kr1C17 → netECA17[Keys@test4Data8kr1C17, {"TopProbabilities", 2}]]
```

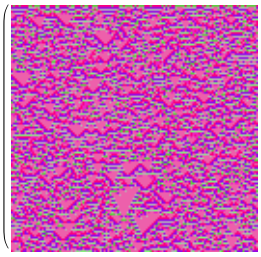
Out[•]=

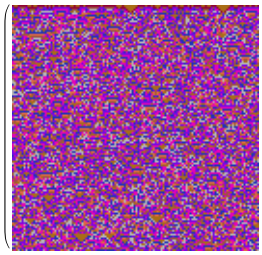

→ 14 955 350 598 586 141 683 → {4 → 1.70104 × 10^-7, 3 → 1.},


→ 30 727 455 169 449 395 964 → {4 → 4.31945 × 10^-11, 3 → 1.},

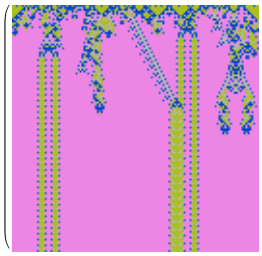

→ 42 490 152 676 883 207 115 → {3 → 0.0000793636, 4 → 0.999921},


→ 18 395 296 261 071 222 192 → {4 → 0.0142026, 3 → 0.985797},

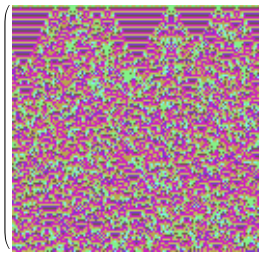

→ 22 317 090 484 634 250 431 → {3 → 0.00783339, 4 → 0.992167},



→ 33 329 414 465 629 594 174 → {4 → 0.00851294, 3 → 0.991487},



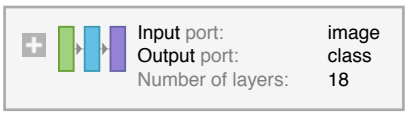
→ 68 439 232 681 205 604 962 → $\{2 \to 1.97568 \times 10^{-13}, 4 \to 1.\}$,



→ 53 049 830 479 062 864 751 → $\{4 \to 3.6815 \times 10^{-10}, 3 \to 1.\}\}$

Network XVIII- Four convolutions, dropout on linear only, BatchNorm

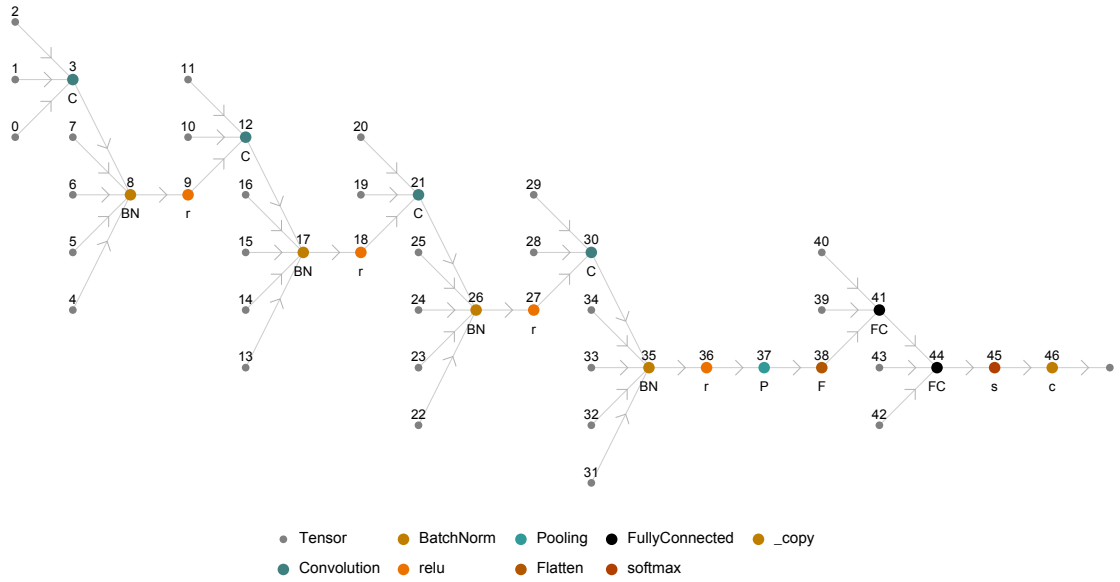
In[•]:= **netECA18 = netTenCC1024drop[128, 128]**

Out[•]= NetChain[

]

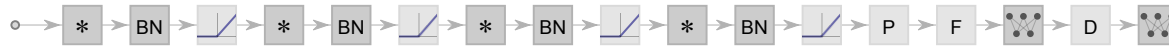
In[•]:=
```
NetInformation[netECA18, "MXNetNodeGraphPlot"]
```

Out[•]=



In[•]:=
```
NetInformation[netECA18, "SummaryGraphic"]
```

Out[•]=



In[•]:=
```
dataECA18 = dataC[128, 128, 16 384];
```

In[•]:=
```
dataTotalistic2BigC18 = genData2r2C[128, 128, 4096];
```

In[•]:=
```
dataTotalistic3BigC18 = data3T2C[128, 128, 4096];
```

In[•]:=
```
dataTotalistic4BigC18 = data4TC[128, 128, 4096];
```

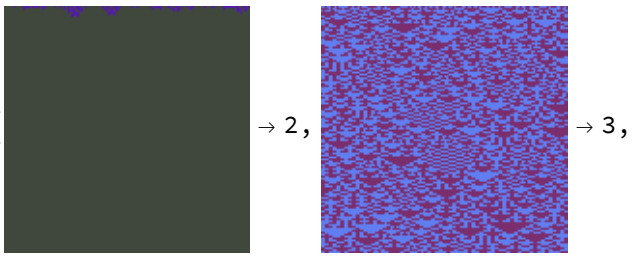
In[•]:=
```
dataTotalistic5BigC18 = genData5TCC[128, 128, 16 384];
```

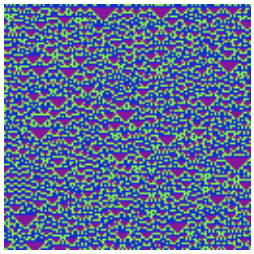
In[•]:=
```
fullTrainingBigC18 = Join[dataECA18, dataTotalistic2BigC18,
   dataTotalistic3BigC18, dataTotalistic4BigC18, dataTotalistic5BigC18];
Length[fullTrainingBigC18]
```

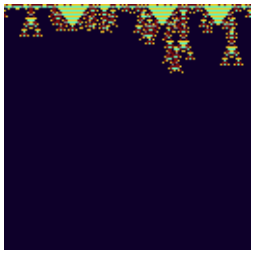
Out[•]=
```
90 112
```

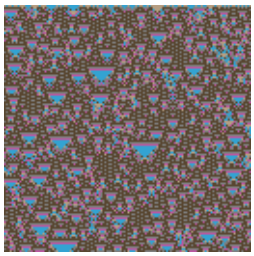
In[•]:=
```
RandomSample[fullTrainingBigC18, 20]
```

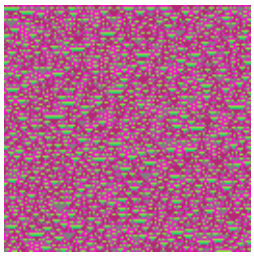
Out[•]=

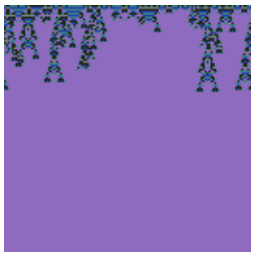
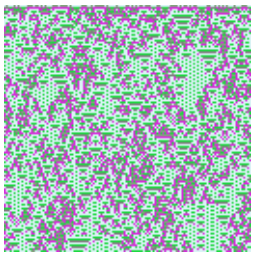
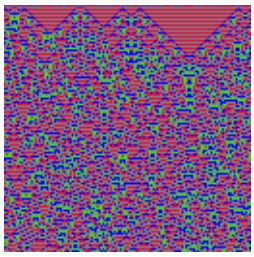



→ 3,

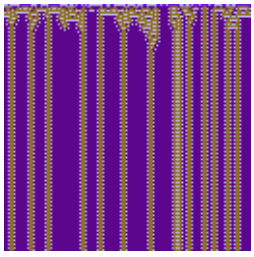
→ 2,

→ 2,

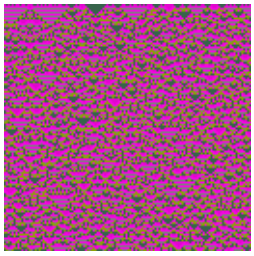
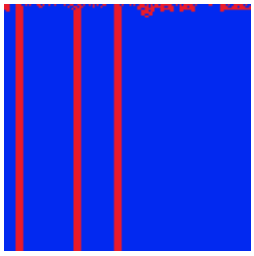
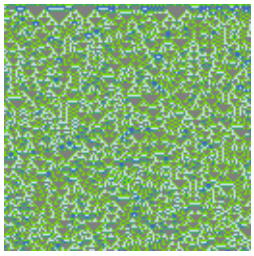

→ 3,

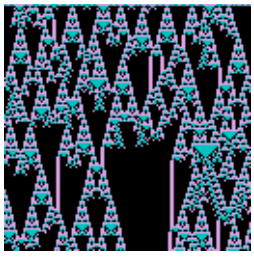
→ 1,

→ 3,


→ 2,

→ 4,

→ 3,


→ 2,

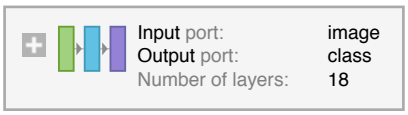
→ 2,

→ 2,


→ 3,

→ 2,

→ 3,

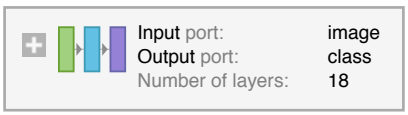

→ 1,

→ 4,

→ 1}

```
In[•]:= dir = SetDirectory[NotebookDirectory[]]
Out[•]= /home/esilverman/Documents

In[•]:= "/home/esilverman/Documents"
Out[•]= /home/esilverman/Documents

In[•]:= netECA18 = NetTrain[netECA18, fullTrainingBigC18,
          MaxTrainingRounds → 200, BatchSize → 256, TargetDevice → "GPU",
          TrainingProgressCheckpointing → {"Directory", dir}]
```

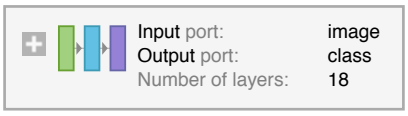
Out[•]= NetChain[]


```
In[•]:= netECA18 = Import["netECA18-r200.wlnet"]
```

Out[•]= NetChain[]

Generate test data for Network XVII (200 epochs)

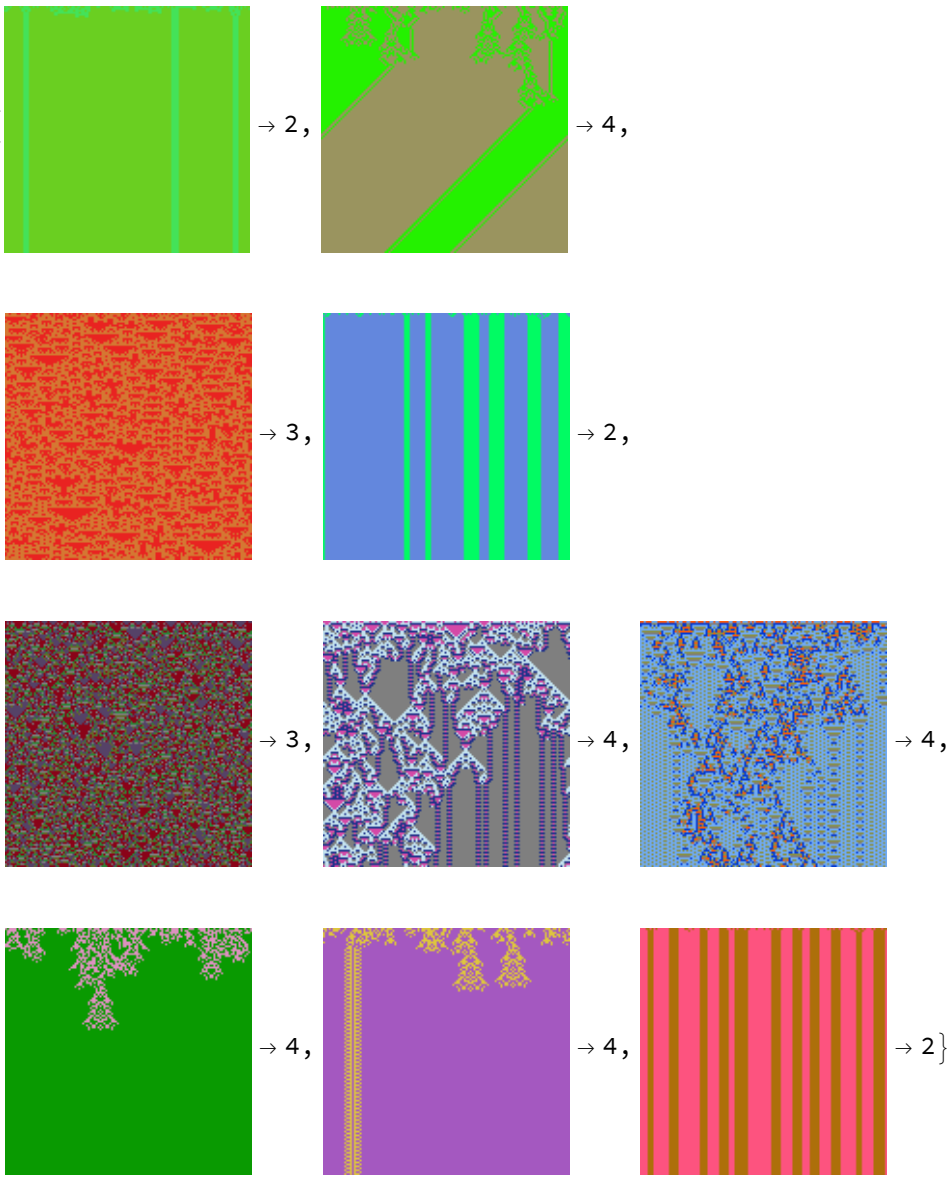
```
In[•]:= dir = SetDirectory[NotebookDirectory[]]
Out[•]= /Users/thorsilver/Downloads/Wolfram notebooks

In[180]:= netECA18 = Import["netECA18-r200.wlnet"]
```

Out[180]= NetChain[]


```
In[•]:= testDataECABigC = dataC[128, 128, 1024];
        testData2TBigC = genData2r2C[128, 128, 1024];
        testData3TBigC = data3T2C[128, 128, 1024];
        testData4TBigC = data4TC[128, 128, 1024];
        testData5TBigC = genData5TCC[128, 128, 1024];
        fullTestSetBigC = Join[testDataECABigC,
           testData2TBigC, testData3TBigC, testData4TBigC, testData5TBigC];
        Length[fullTestSetBigC]
Out[•]= 10 240
```

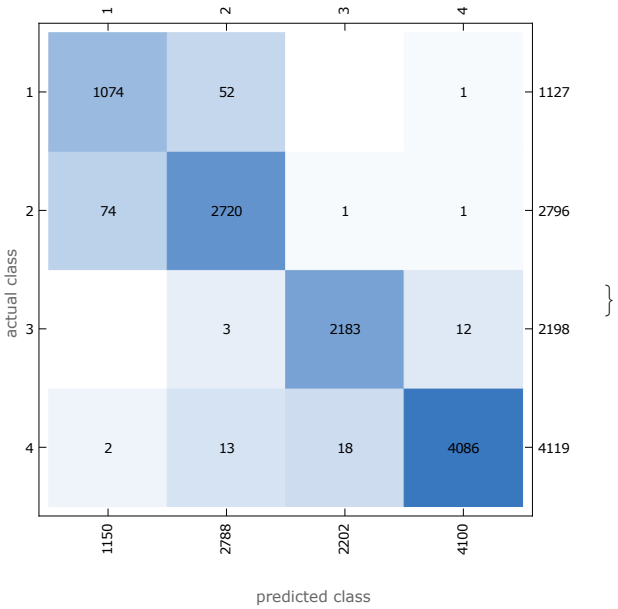
In[•]:= `RandomSample[fullTestSetBigC, 10]`

Out[•]=



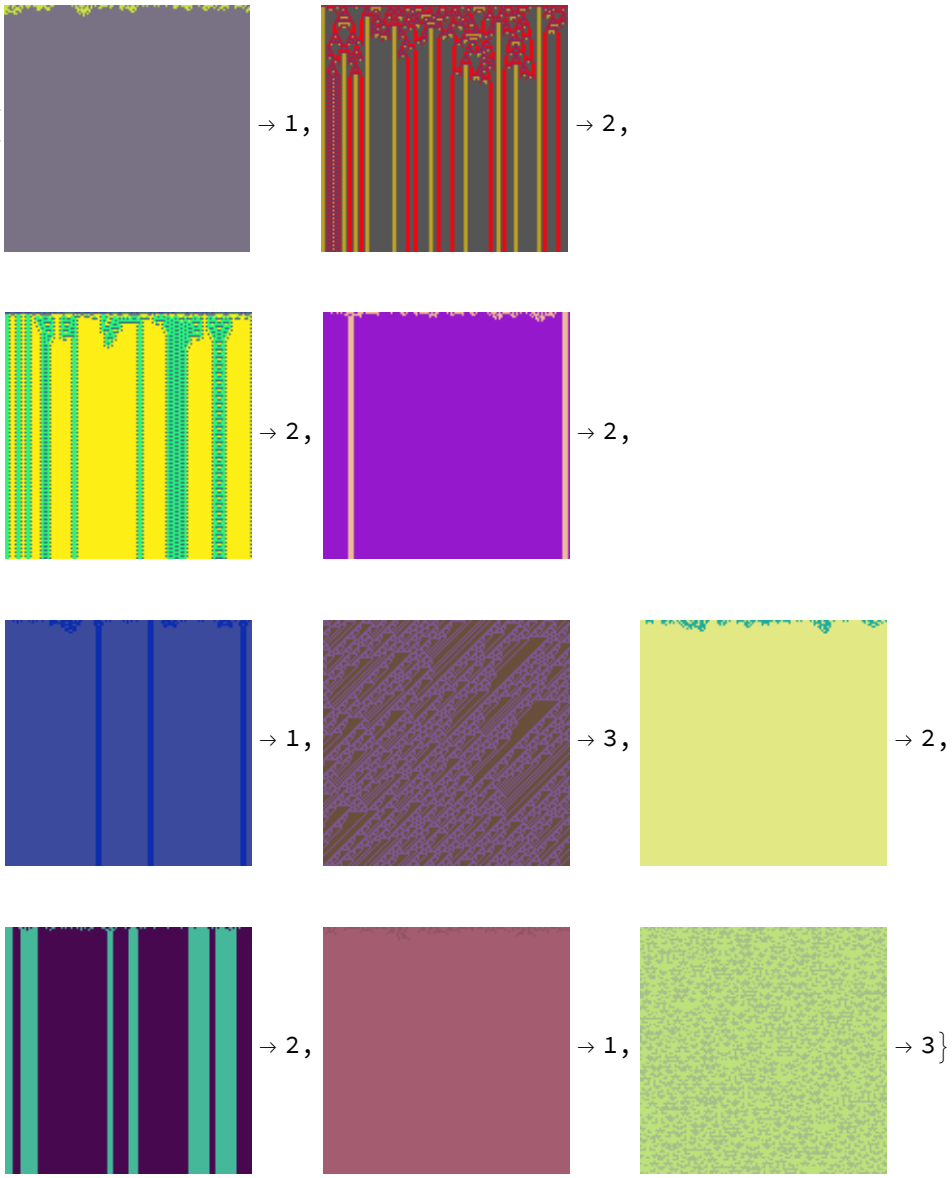
In[181]:=
```
NetMeasurements[netECA18, fullTestSetBigC,
 {"Accuracy", "Precision", "ConfusionMatrixPlot"}]
```

Out[181]=
```
{0.982715, ⟨|1 → 0.933913, 2 → 0.97561, 3 → 0.991371, 4 → 0.996585|⟩,
```

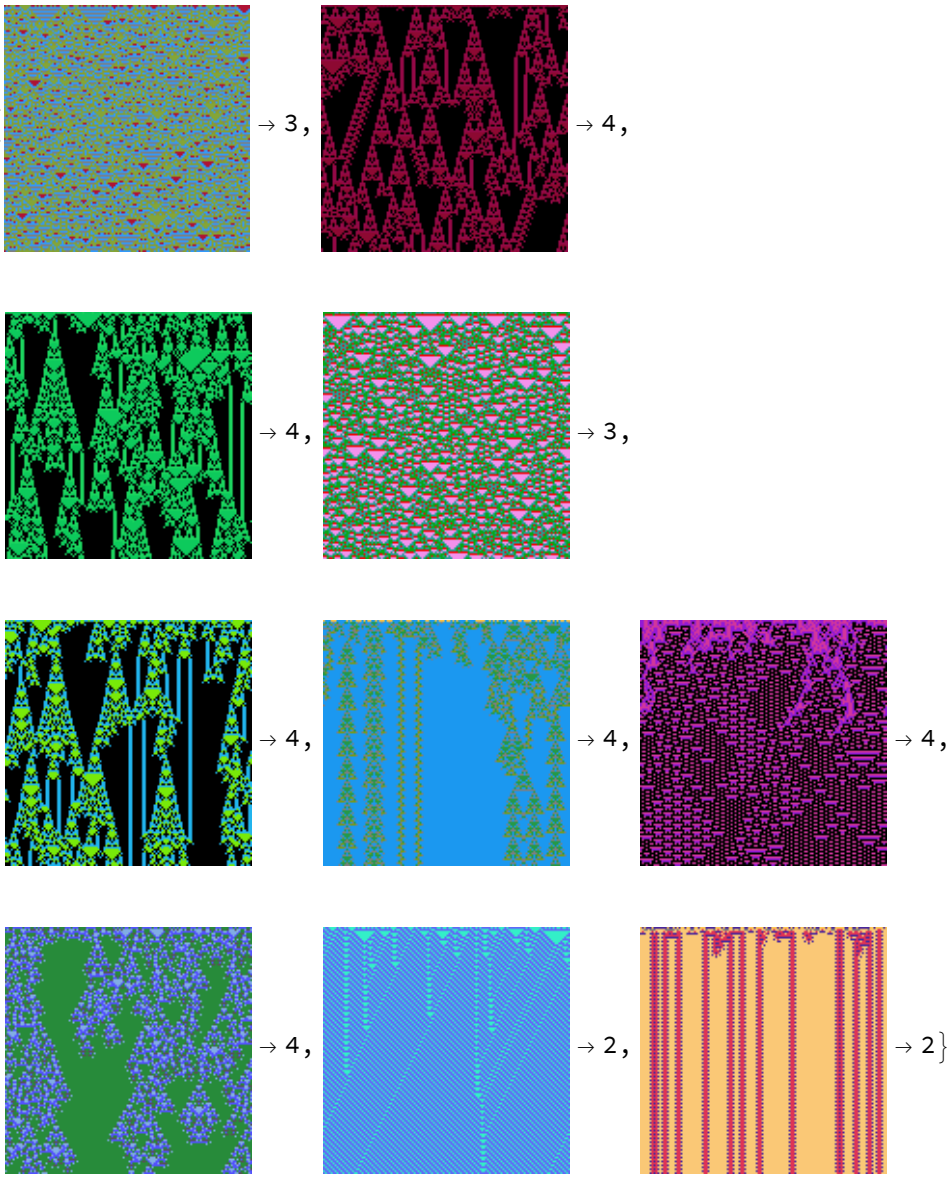


In[188]:=
```
entropyImagesBigC = RandomSample[Keys[fullTestSetBigC], 500];
entropiesBigC = netECA18[entropyImagesBigC, "Entropy"];
highEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, -10]]];
lowEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, 10]]];
Thread[highEntBigC → netECA18[highEntBigC]]
Thread[lowEntBigC → netECA18[lowEntBigC]]
```

Out[192]=



Out[193]=

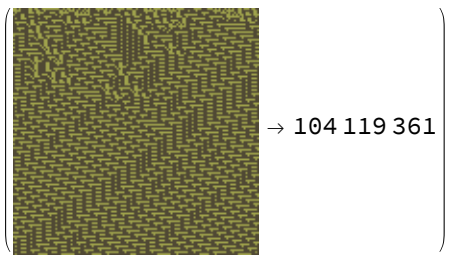


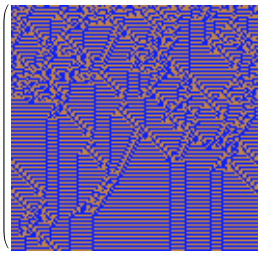
Testing Network XVIII (200 epochs) on unseen CA rule spaces

2-colour non-totalistic, range 2

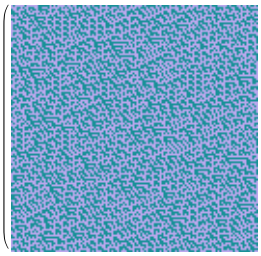
In[194]:=
```
test4Data2kr2C18 = datak2r2C[128, 128, 8];
Thread[
 test4Data2kr2C18 → netECA18[Keys@test4Data2kr2C18, {"TopProbabilities", 2}]]
```

Out[195]=

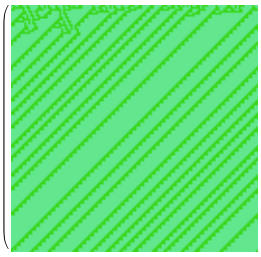




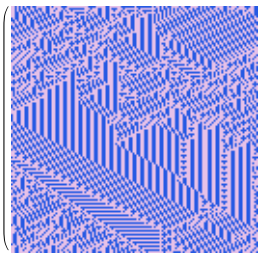
$\to 426\,073\,771 \Big| \to \{3 \to 0.0891399, 4 \to 0.910856\},$



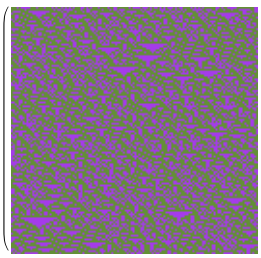
$\to 1\,487\,290\,163 \Big| \to \{4 \to 8.29353 \times 10^{-14}, 3 \to 1.\},$



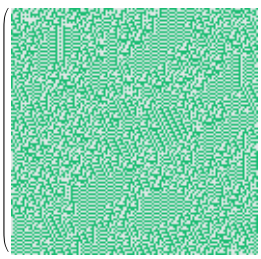
$\to 3\,761\,497\,755 \Big| \to \{4 \to 0.484906, 3 \to 0.514237\},$



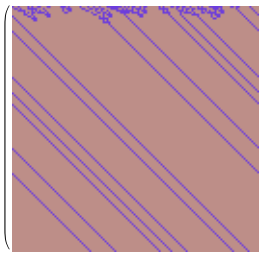
$\to 1\,503\,689\,727 \Big| \to \{3 \to 6.00879 \times 10^{-8}, 4 \to 1.\},$



$\to 2\,106\,940\,334 \Big| \to \{4 \to 5.44016 \times 10^{-23}, 3 \to 1.\},$



$\to 2\,590\,447\,558 \Big| \to \{4 \to 2.78794 \times 10^{-8}, 3 \to 1.\},$



→ 4 213 015 958 → {1 → 2.47284 × 10^-12, 2 → 1.}}

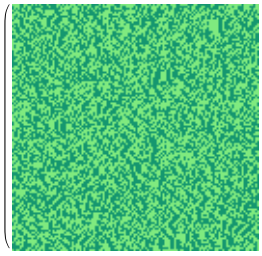
2-colour non-totalistic, range 3

In[•]:=
```
test4Data2kr3C18 = datak2r3NT[128, 128, 8];
Thread[
 test4Data2kr3C18 → netECA18[Keys@test4Data2kr3C18, {"TopProbabilities", 2}]]
```

Out[•]=

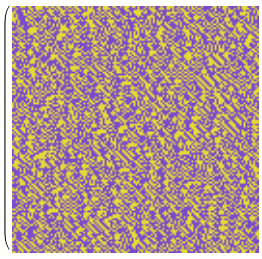
→ 330 416 984 885 540 388 017 354 162 041 951 825 587 →

{3 → 8.74296 × 10^-8, 4 → 1.},



→ 279 656 361 264 376 888 074 030 685 915 728 704 181 →

{4 → 0.0213521, 3 → 0.978648},

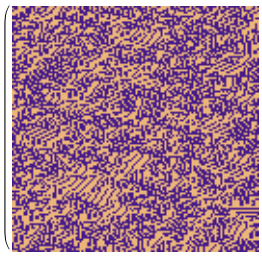


→ 197 632 068 292 332 388 955 030 541 940 304 062 122 →

{4 → 5.0499 × 10^-16, 3 → 1.},

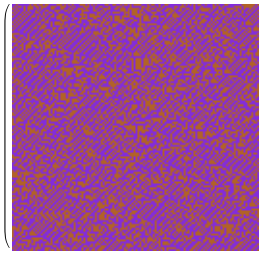
→ 188 082 660 194 176 799 122 844 083 244 865 677 445 →

$\{4 \to 2.34238 \times 10^{-6}, 3 \to 0.999998\}$,



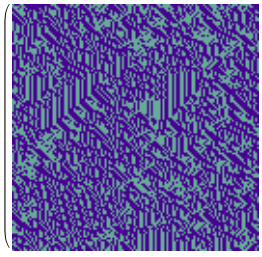
→ 99 467 121 511 183 621 679 443 804 486 384 512 063 →

$\{4 \to 0.00329566, 3 \to 0.996704\}$,



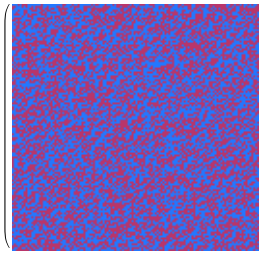
→ 56 219 309 346 455 872 630 743 597 889 899 213 800 →

$\{4 \to 1.38574 \times 10^{-10}, 3 \to 1.\}$,



→ 308 130 247 560 683 500 868 656 567 738 983 907 586 →

$\{4 \to 5.1263 \times 10^{-8}, 3 \to 1.\}$,

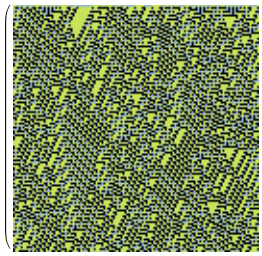


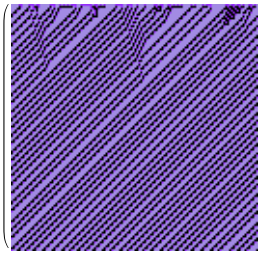
→ 333 388 526 947 822 905 616 741 326 831 869 137 342 →

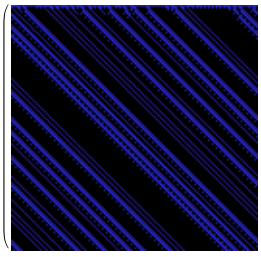
$\{4 \to 7.10494 \times 10^{-8}, 3 \to 1.\}\}$

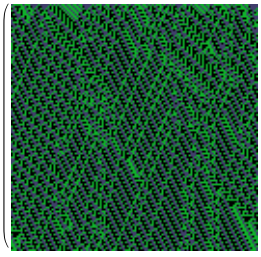
3-colour non-totalistic, range 1

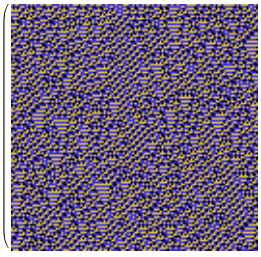
In[•]:=
```
test4Data3kr1C18 = datak3r1NT[128, 128, 8];
Thread[
 test4Data3kr1C18 → netECA18[Keys@test4Data3kr1C18, {"TopProbabilities", 2}]]
```

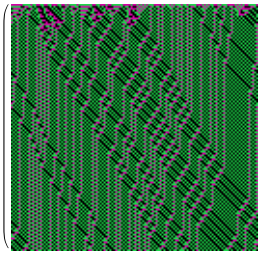
Out[•]= {  → 1 592 394 332 064 → {2 → 7.59314 × 10^-6, 4 → 0.999992},

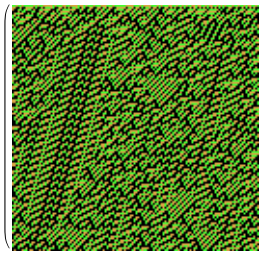
 → 4 098 174 485 356 → {4 → 8.44302 × 10^-20, 2 → 1.},

 → 5 930 373 291 731 → {1 → 2.34989 × 10^-7, 2 → 1.},

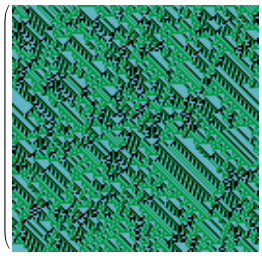
 → 6 363 744 081 807 → {3 → 0.0000390704, 4 → 0.999961},

 → 1 193 083 886 293 → {4 → 0.0126455, 3 → 0.987355},

 → 1 957 822 902 340 → {3 → 0.0000561806, 2 → 0.999944},



$\to 2\,179\,566\,018\,820 \to \{4 \to 1.10915 \times 10^{-6}, 3 \to 0.999999\},$

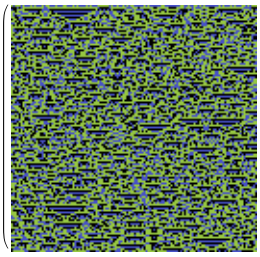


$\to 4\,111\,476\,009\,175 \to \{4 \to 1.84666 \times 10^{-16}, 3 \to 1.\}\}$

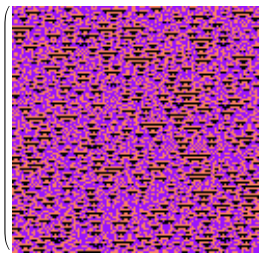
3-colour totalistic, range 2

In[•]:=
```
test4Data3kr2C18 = datak3r2C[128, 128, 8];
Thread[
 test4Data3kr2C18 → netECA18[Keys@test4Data3kr2C18, {"TopProbabilities", 2}]]
```

Out[•]=

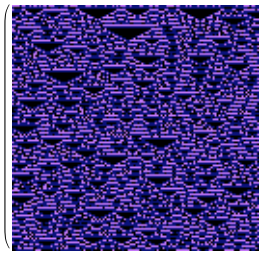


$\to 101\,105 \to \{4 \to 1.49159 \times 10^{-7}, 3 \to 1.\},$

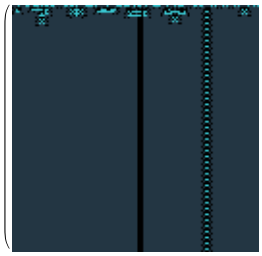


$\to 48\,212 \to \{4 \to 3.39887 \times 10^{-8}, 3 \to 1.\},$

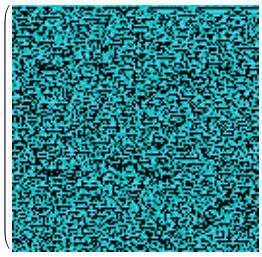
$\to 81\,243 \to \{2 \to 6.61823 \times 10^{-15}, 1 \to 1.\},$



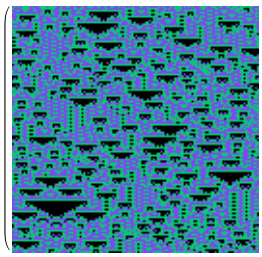
$\to 144\,952 \to \{4 \to 5.58692 \times 10^{-14}, 3 \to 1.\},$



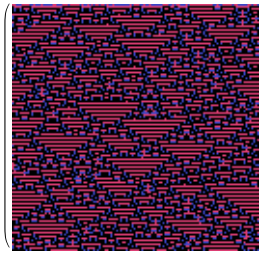
$\to 167\,730 \to \{1 \to 3.79715 \times 10^{-7}, 2 \to 1.\},$



$\to 102\,220 \to \{4 \to 3.5215 \times 10^{-7}, 3 \to 1.\},$



$\to 129\,071 \to \{4 \to 5.28522 \times 10^{-29}, 3 \to 1.\},$

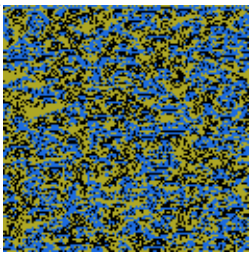


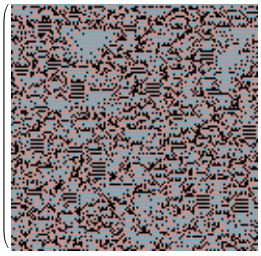
$\to 94\,027 \to \{4 \to 3.95426 \times 10^{-7}, 3 \to 1.\}\}$

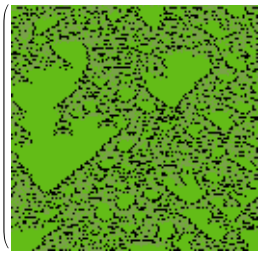
3-colour totalistic, range 3

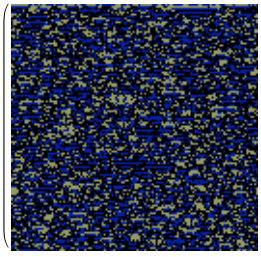
In[•]:=
```
test4Data3kr3C18 = datak3r3C[128, 128, 8];
Thread[
 test4Data3kr3C18 → netECA18[Keys@test4Data3kr3C18, {"TopProbabilities", 2}]]
```

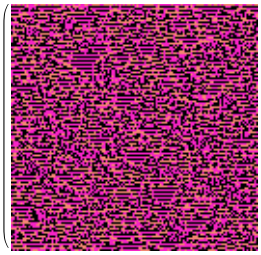
Out[•]= {

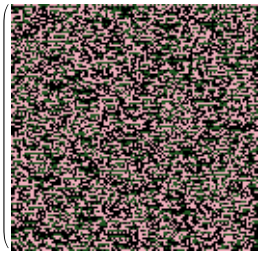

→ 461 960 → {4 → 4.84455 × 10^-6, 3 → 0.999995},

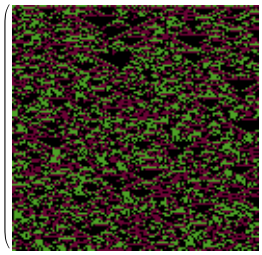

→ 4 823 863 → {4 → 1.80913 × 10^-22, 3 → 1.},


→ 7 272 180 → {3 → 3.43734 × 10^-9, 4 → 1.},

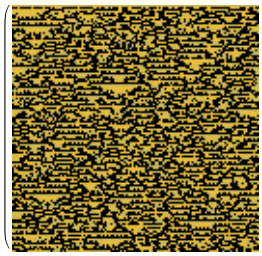

→ 8 672 980 → {4 → 6.70981 × 10^-6, 3 → 0.999993},


→ 254 357 → {4 → 2.17773 × 10^-6, 3 → 0.999998},


→ 9 226 537 → {4 → 1.70317 × 10^-12, 3 → 1.},



→ 13 913 899 → {4 → 1.88245 × 10^-14, 3 → 1.},

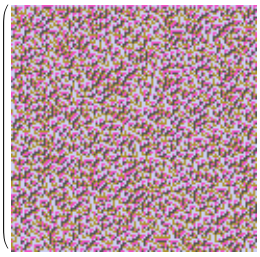


→ 2 641 642 → {4 → 1.17168 × 10^-16, 3 → 1.}}

4-colour non-totalistic, range 1

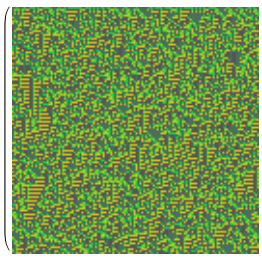
In[•]:=
```
test4Data4kr1C18 = datak4r1NT[128, 128, 8];
Thread[
 test4Data4kr1C18 → netECA18[Keys@test4Data4kr1C18, {"TopProbabilities", 2}]]
```

Out[•]=



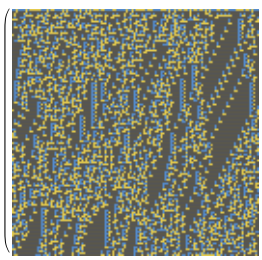
→ 102 061 531 028 325 101 056 411 203 373 159 921 153 →

{4 → 1.52655 × 10^-6, 3 → 0.999998},



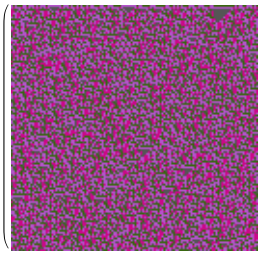
→ 220 826 430 777 843 014 546 276 939 581 509 597 468 →

{4 → 3.71156 × 10^-15, 3 → 1.},



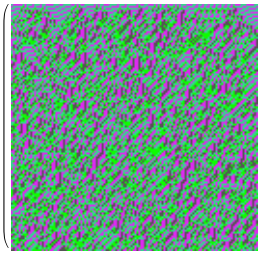
→ 189 759 227 742 452 338 669 016 752 488 159 725 978 →

$\{3 \to 1.71606 \times 10^{-19}, 4 \to 1.\}$,



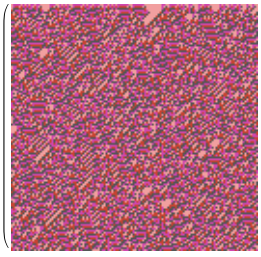
$\to 39\,086\,343\,891\,936\,177\,646\,298\,077\,938\,677\,400\,893 \to$

$\{4 \to 0.0000617923, 3 \to 0.999938\}$,



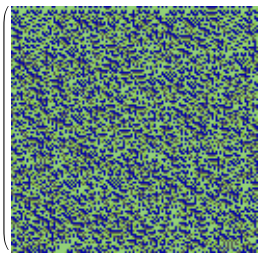
$\to 325\,561\,419\,730\,770\,765\,208\,110\,988\,081\,624\,688\,453 \to$

$\{4 \to 4.25321 \times 10^{-7}, 3 \to 1.\}$,



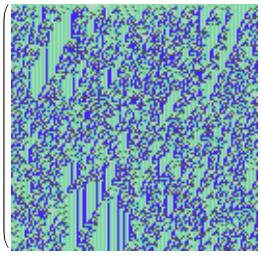
$\to 247\,405\,682\,417\,519\,114\,838\,497\,454\,468\,289\,242\,544 \to$

$\{4 \to 3.94091 \times 10^{-12}, 3 \to 1.\}$,



$\to 173\,148\,209\,233\,830\,655\,560\,355\,066\,654\,224\,721\,166 \to$

$\{4 \to 1.19081 \times 10^{-14}, 3 \to 1.\}$,



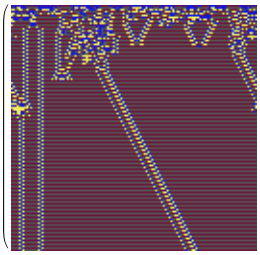
$\to 272\,790\,974\,570\,863\,467\,026\,653\,486\,918\,315\,112\,723 \to$

$\{3 \to 2.26679 \times 10^{-10}, 4 \to 1.\}\}$

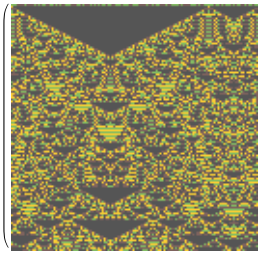
4-colour totalistic, range 2

In[•]:=
```
test4Data4kr2C18 = datak4r2C[128, 128, 8];
Thread[
 test4Data4kr2C18 → netECA18[Keys@test4Data4kr2C18, {"TopProbabilities", 2}]]
```

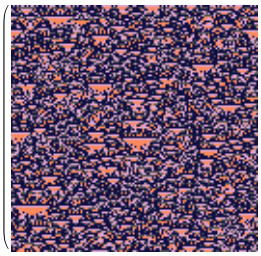
Out[•]=



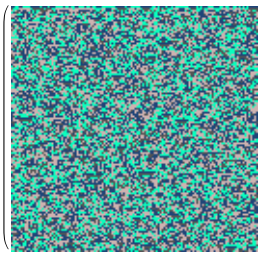
→ 3 511 876 239 → {2 → 1.5807 × 10^-10, 4 → 1.},



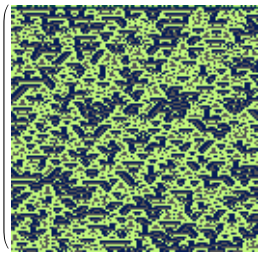
→ 1 629 765 289 → {4 → 1.84811 × 10^-17, 3 → 1.},



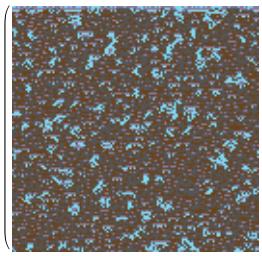
→ 3 309 785 711 → {4 → 5.75659 × 10^-20, 3 → 1.},

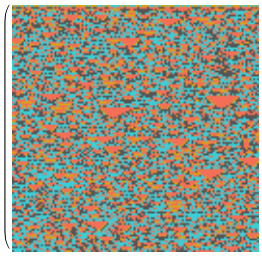


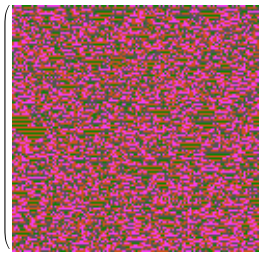
→ 521 880 538 → {4 → 2.42952 × 10^-8, 3 → 1.},



→ 2 882 903 289 → {4 → 0.00262183, 3 → 0.997378},


→ 3 874 370 131 → {4 → 0.000817121, 3 → 0.999183},

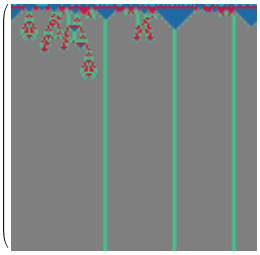

→ 3 978 874 812 → $\{4 \to 4.99897 \times 10^{-19}, 3 \to 1.\}$,

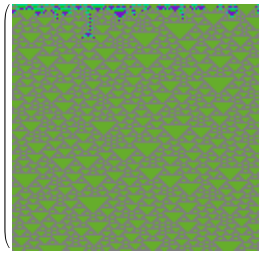

→ 1 758 609 338 → $\{4 \to 1.64955 \times 10^{-9}, 3 \to 1.\}\}$

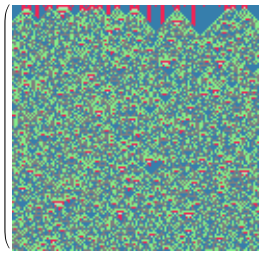
5-colour totalistic, range 1

In[•]:=
```
test4Data5kr1C18 = data5T2C[8, 128, 128];
Thread[
 test4Data5kr1C18 → netECA18[Keys@test4Data5kr1C18, {"TopProbabilities", 2}]]
```

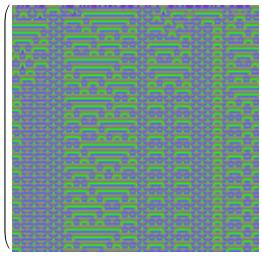
Out[•]=


→ 419 338 996 → {4 → 0.471539, 2 → 0.528461},

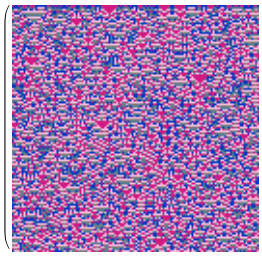

→ 884 788 964 → {4 → 0.0217201, 3 → 0.97828},



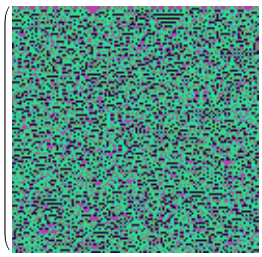
$\to 743\,542\,029 \Big| \to \{3 \to 1.08355 \times 10^{-9}, 4 \to 1.\},$



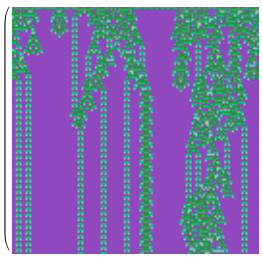
$\to 782\,108\,342 \Big| \to \{4 \to 3.73846 \times 10^{-6}, 3 \to 0.999996\},$



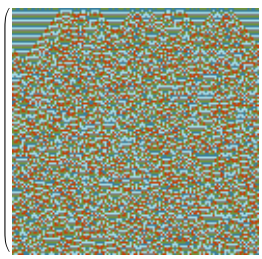
$\to 785\,621\,045 \Big| \to \{4 \to 1.13554 \times 10^{-10}, 3 \to 1.\},$



$\to 540\,834\,160 \Big| \to \{4 \to 0.0000100212, 3 \to 0.99999\},$



$\to 1\,180\,125\,611 \Big| \to \{3 \to 8.69272 \times 10^{-10}, 4 \to 1.\},$

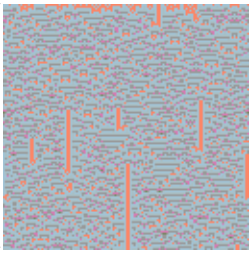


$\to 604\,699\,906 \Big| \to \{4 \to 5.02809 \times 10^{-11}, 3 \to 1.\}\}$

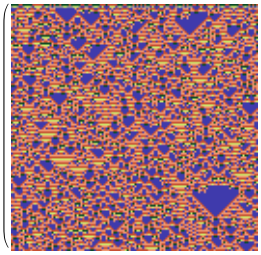
6-colour totalistic, range 1

```
In[•]:= test4Data6kr1C18 = data6TC[8, 128, 128];
        Thread[
         test4Data6kr1C18 → netECA18[Keys@test4Data6kr1C18, {"TopProbabilities", 2}]]
```

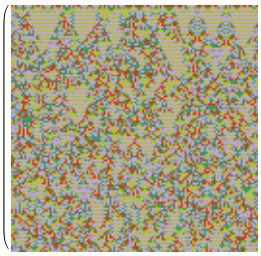
Out[•]=



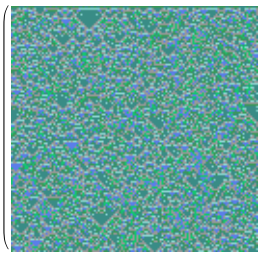
→ 1 598 104 240 744 → {4 → 0.385354, 3 → 0.614646},



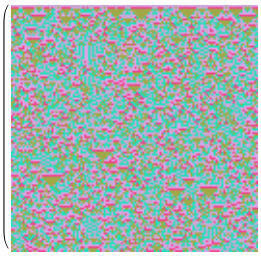
→ 2 744 610 103 617 → {4 → 4.14684 × 10^-12, 3 → 1.},



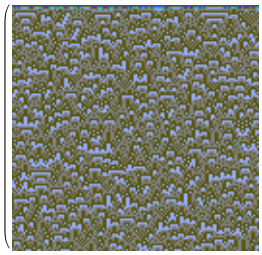
→ 2 679 723 007 553 → {4 → 0.0146554, 3 → 0.985345},

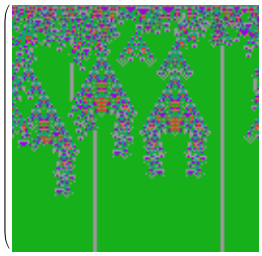


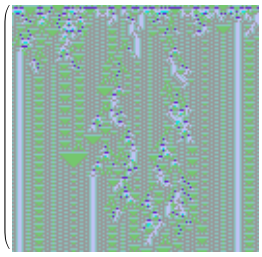
→ 333 206 194 422 → {4 → 1.77212 × 10^-6, 3 → 0.999998},



→ 385 745 608 648 → {4 → 4.96414 × 10^-18, 3 → 1.},

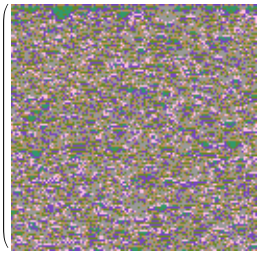

→ 1 376 556 791 013 → {4 → 1.60883 × 10^-6, 3 → 0.999998},

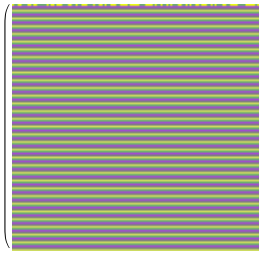

→ 1 497 722 744 619 → {2 → 5.2004 × 10^-22, 4 → 1.},

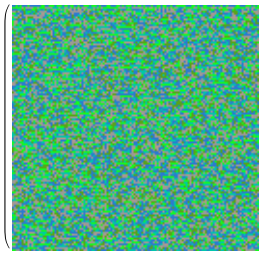

→ 1 461 122 595 667 → {4 → 0.0117104, 3 → 0.98829}}

6-colour totalistic, range 2

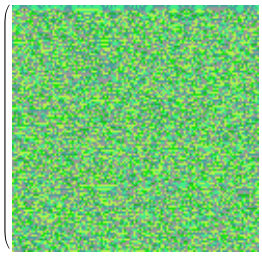
In[•]:=
```
test4Data6kr2C18 = data6T2C[8, 128, 128];
Thread[
 test4Data6kr2C18 → netECA18[Keys@test4Data6kr2C18, {"TopProbabilities", 2}]]
```

Out[•]=
{ 
→ 94 758 619 520 606 075 339 → {4 → 3.45801 × 10^-14, 3 → 1.},

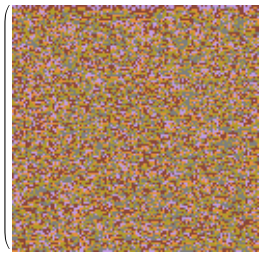

→ 20 009 329 597 666 396 569 → {1 → 0.000569901, 3 → 0.999395},



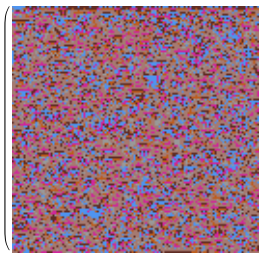
$\to 143\,751\,744\,015\,528\,766\,387 \Big| \to \{4 \to 4.63781 \times 10^{-12}, 3 \to 1.\},$



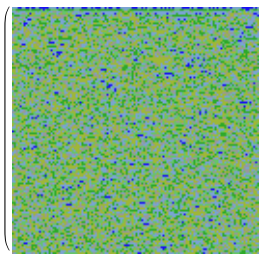
$\to 14\,907\,007\,420\,911\,525\,245 \Big| \to \{4 \to 2.71632 \times 10^{-7}, 3 \to 1.\},$



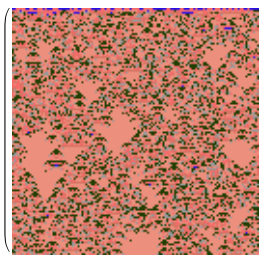
$\to 153\,725\,842\,134\,059\,084\,151 \Big| \to \{4 \to 8.53867 \times 10^{-11}, 3 \to 1.\},$



$\to 21\,849\,107\,846\,366\,361\,856 \Big| \to \{4 \to 4.26147 \times 10^{-8}, 3 \to 1.\},$



$\to 39\,897\,609\,306\,289\,130\,946 \Big| \to \{4 \to 3.43225 \times 10^{-8}, 3 \to 1.\},$

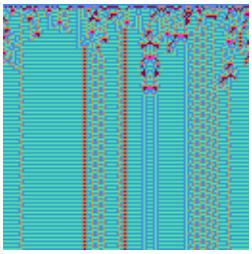


$\to 24\,452\,844\,112\,980\,510\,505 \Big| \to \{3 \to 2.30799 \times 10^{-17}, 4 \to 1.\}\}$

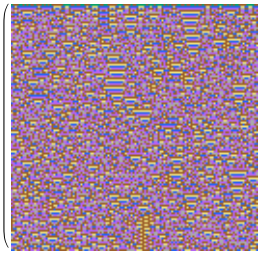
7-colour totalistic, range 1

```
In[•]:= test4Data7kr1C18 = data7TC[8, 128, 128];
        Thread[
         test4Data7kr1C18 → netECA18[Keys@test4Data7kr1C18, {"TopProbabilities", 2}]]
```

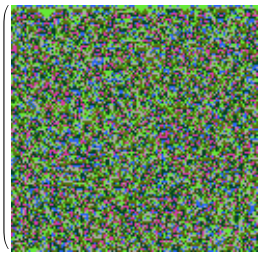
Out[•]=



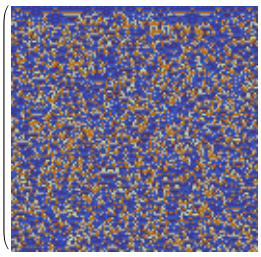
→ 9 377 524 399 313 965 → {3 → 1.74389 × 10^-8, 4 → 1.},



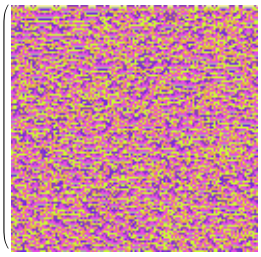
→ 4 962 953 862 340 599 → {4 → 0.0137316, 3 → 0.986268},



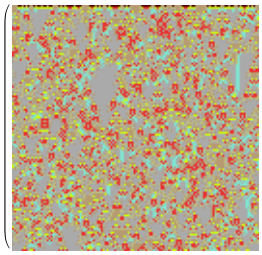
→ 8 745 570 953 687 246 → {4 → 2.19284 × 10^-7, 3 → 1.},

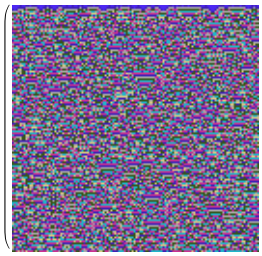


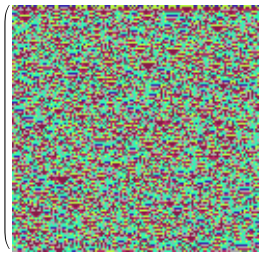
→ 5 868 018 872 447 407 → {4 → 0.000111761, 3 → 0.999888},



→ 4 309 418 628 605 253 → {4 → 1.75407 × 10^-6, 3 → 0.999998},

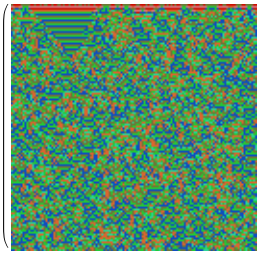

→ 602 881 578 564 447 → {3 → 1.85106 × 10^-9, 4 → 1.},

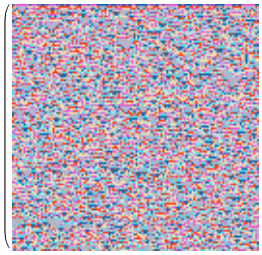

→ 2 664 890 136 425 923 → {4 → 3.52309 × 10^-12, 3 → 1.},

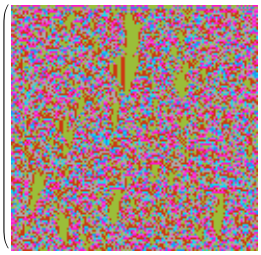

→ 2 116 828 975 265 896 → {4 → 3.12886 × 10^-9, 3 → 1.}}

8-colour totalistic, range 1

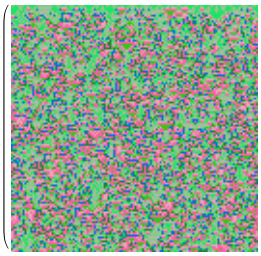
In[•]:=
```
test4Data8kr1C18 = data8TC[8, 128, 128];
Thread[
 test4Data8kr1C18 → netECA18[Keys@test4Data8kr1C18, {"TopProbabilities", 2}]]
```

Out[•]=
{ 
→ 4 354 635 422 940 040 188 → {4 → 0.0522672, 3 → 0.947733},

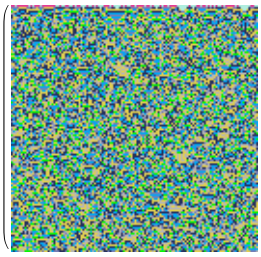

→ 69 178 369 869 620 121 447 → {4 → 1.13339 × 10^-12, 3 → 1.},



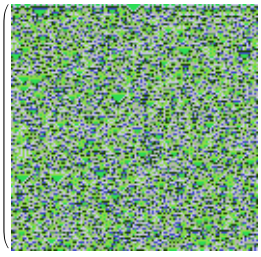
→ 52 954 223 906 783 093 008 → {3 → 7.29147 × 10^-15, 4 → 1.},



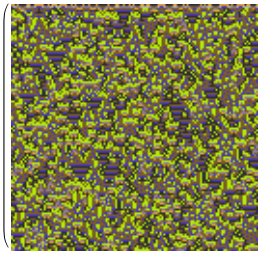
→ 68 658 165 468 973 438 000 → {4 → 1.9166 × 10^-11, 3 → 1.},



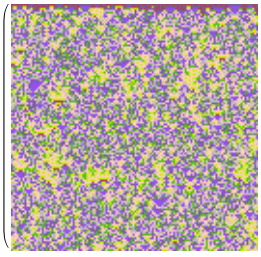
→ 40 882 704 313 683 534 715 → {4 → 0.0000183002, 3 → 0.999982},



→ 4 334 236 228 138 547 400 → {4 → 1.8216 × 10^-12, 3 → 1.},



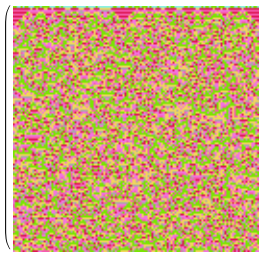
→ 38 056 813 477 139 716 563 → {4 → 0.025224, 3 → 0.974776},



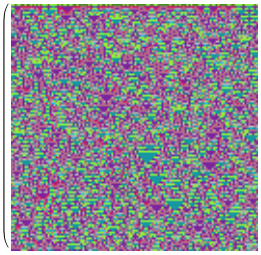
→ 17 144 034 197 046 476 300 → {4 → 1.1918 × 10^-10, 3 → 1.}}

```
In[•]:= test4Data8kr1C18 = data8TC[8, 128, 128];
        Thread[
         test4Data8kr1C18 → netECA18[Keys@test4Data8kr1C18, {"TopProbabilities", 2}]]
```

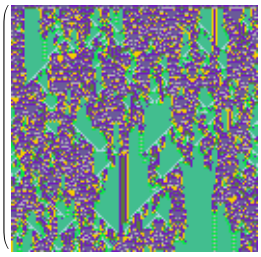
Out[•]=



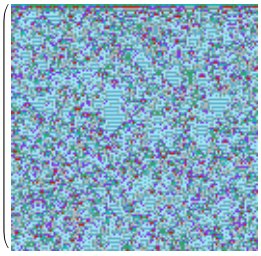
→ 27 295 602 810 117 462 452 → {4 → 1.93716 × 10^-14, 3 → 1.},



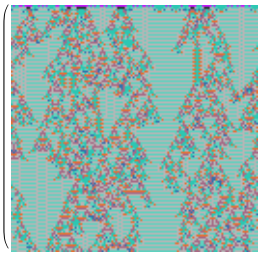
→ 68 187 226 482 692 112 227 → {4 → 1.97888 × 10^-15, 3 → 1.},



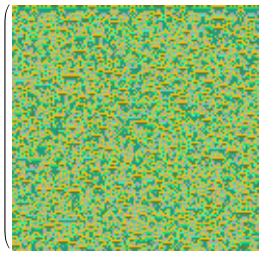
→ 26 338 422 679 712 858 793 → {2 → 1.54265 × 10^-15, 4 → 1.},

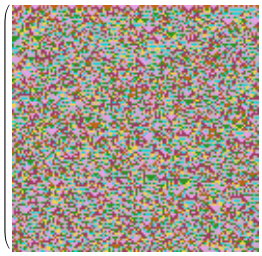


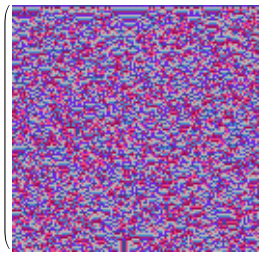
→ 20 106 191 194 925 098 456 → {4 → 1.32784 × 10^-9, 3 → 1.},



→ 27 427 530 853 867 733 909 → {3 → 7.69696 × 10^-6, 4 → 0.999992},


→ 67 626 281 665 658 424 537 → {4 → 1.31383 × 10^-8, 3 → 1.},

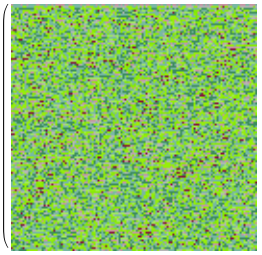

→ 25 326 375 293 896 897 208 → {4 → 9.39517 × 10^-8, 3 → 1.},


→ 17 284 363 590 068 343 962 → {4 → 0.000164327, 3 → 0.999836}}

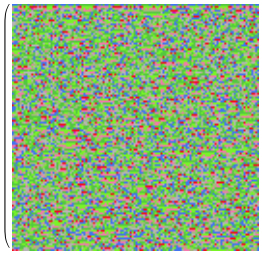
8-colour totalistic, range 2

In[•]:=
```
test4Data8kr2C18 = data8T2C[8, 128, 128];
Thread[
 test4Data8kr2C18 → netECA18[Keys@test4Data8kr2C18, {"TopProbabilities", 2}]]
```

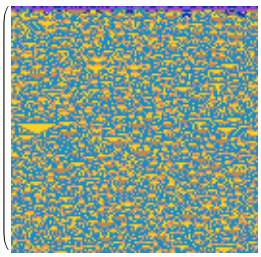
Out[•]=


→ 91 605 229 994 459 866 473 701 555 510 459 →

{4 → 8.95721 × 10^-9, 3 → 1.},

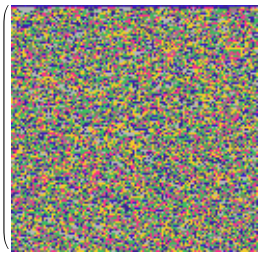

→ 148 194 329 210 486 766 360 332 149 681 908 →

{4 → 0.000259168, 3 → 0.999741},



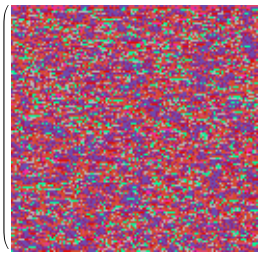
→ 312 941 122 843 853 005 350 894 081 598 045 →

$\{4 \to 3.01437 \times 10^{-25}, 3 \to 1.\}$,



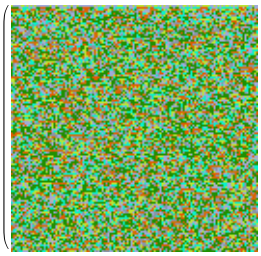
→ 218 758 040 018 464 082 211 209 760 600 342 →

$\{4 \to 1.84707 \times 10^{-6}, 3 \to 0.999998\}$,



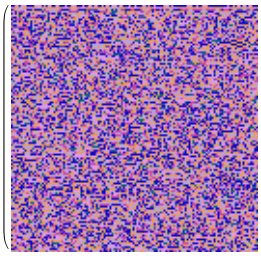
→ 1 618 101 134 718 809 353 656 768 953 028 →

$\{4 \to 8.91462 \times 10^{-12}, 3 \to 1.\}$,



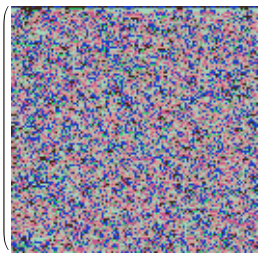
→ 117 778 321 396 037 048 003 724 837 215 261 →

$\{4 \to 1.56349 \times 10^{-7}, 3 \to 1.\}$,



→ 158 334 416 764 854 082 261 529 458 487 247 →

$\{3 \to 0.381514, 4 \to 0.618486\}$,



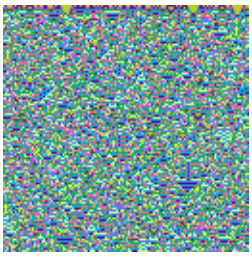
→ 64 962 204 199 289 039 065 352 424 560 944 | →

$\{4 \to 3.15489 \times 10^{-10}, 3 \to 1.\}\}$

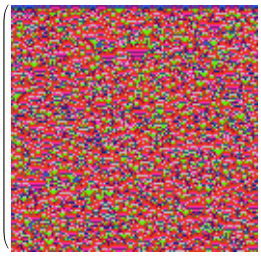
9-colour totalistic, range 1

In[•]:=
```
test4Data9kr1C18 = data9TC[8, 128, 128];
Thread[
 test4Data9kr1C18 → netECA18[Keys@test4Data9kr1C18, {"TopProbabilities", 2}]]
```

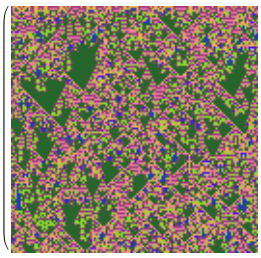
Out[•]=



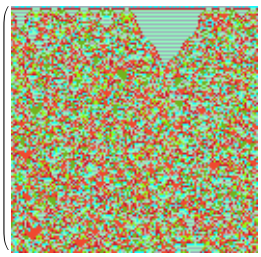
$\{ \to 522\,568\,741\,028\,775\,861\,250\,602 \to \{4 \to 1.89765 \times 10^{-9}, 3 \to 1.\},$



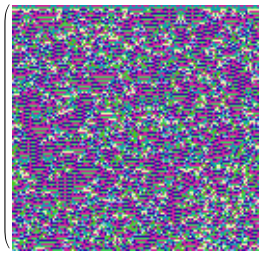
$\to 150\,105\,663\,552\,960\,221\,109\,656 \to \{4 \to 8.50808 \times 10^{-11}, 3 \to 1.\},$

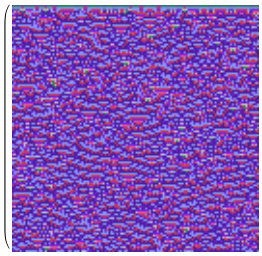


$\to 177\,646\,283\,305\,699\,098\,325\,471 \to \{3 \to 2.75142 \times 10^{-13}, 4 \to 1.\},$

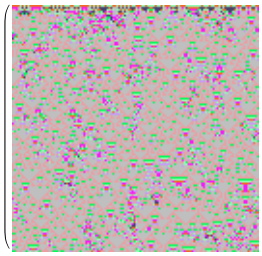


$\to 649\,888\,623\,407\,447\,388\,665\,878 \to \{4 \to 9.1783 \times 10^{-8}, 3 \to 1.\},$

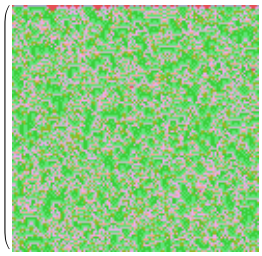

→ 572 736 978 221 231 214 545 140 → {4 → 1.19931 × 10^-8, 3 → 1.},


→ 577 735 506 397 144 743 916 701 →

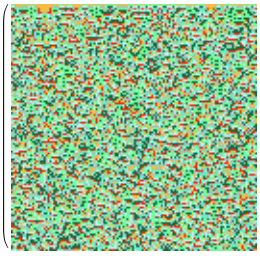
{4 → 5.16186 × 10^-6, 3 → 0.999995},

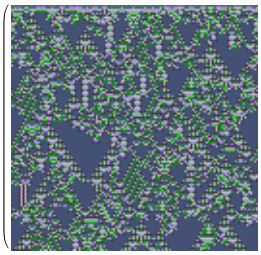

→ 38 290 460 957 561 945 226 664 →

{4 → 0.0000332421, 3 → 0.999967},

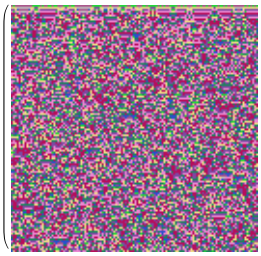

→ 65 266 980 214 577 653 296 276 → {4 → 2.0037 × 10^-9, 3 → 1.}}

In[•]:=
```
test4Data9kr1C18 = data9TC[8, 128, 128];
Thread[
 test4Data9kr1C18 → netECA18[Keys@test4Data9kr1C18, {"TopProbabilities", 2}]]
```

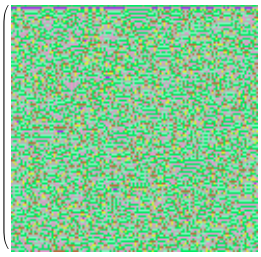
Out[•]= { 
→ 376 251 875 419 739 043 750 089 → {4 → 8.56952 × 10^-8, 3 → 1.},



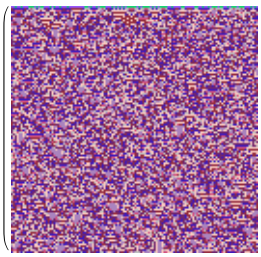
→ 292 480 217 936 066 672 681 870 → $\{3 \to 5.77312 \times 10^{-11}, 4 \to 1.\}$,



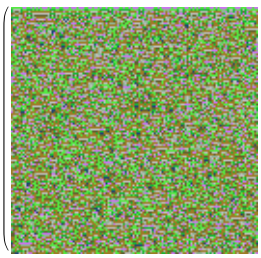
→ 641 652 971 419 956 634 593 698 → $\{4 \to 9.34668 \times 10^{-11}, 3 \to 1.\}$,



→ 560 384 664 222 257 507 134 238 → $\{4 \to 1.28321 \times 10^{-8}, 3 \to 1.\}$,

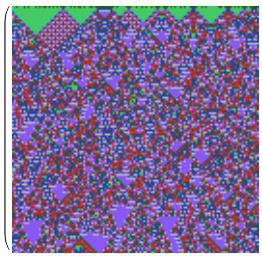


→ 431 262 759 200 417 990 085 248 → $\{4 \to 0.000429963, 3 \to 0.99957\}$,

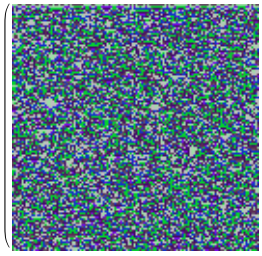


→ 349 851 539 333 502 282 320 618 →

$\{4 \to 5.50927 \times 10^{-7}, 3 \to 0.999999\}$,

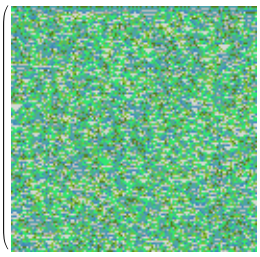

→ 141 618 270 878 027 879 702 319 →

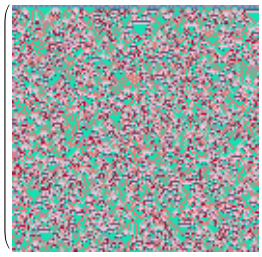
{4 → 0.0000610287, 3 → 0.999939},

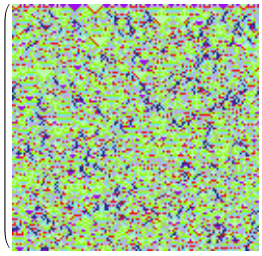

→ 401 516 309 538 894 848 288 118 → {4 → 6.7734 × 10^-12, 3 → 1.}}

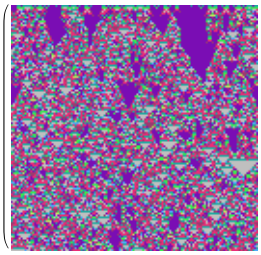
In[•]:=
```
test4Data9kr1C18 = data9TC[8, 128, 128];
Thread[
 test4Data9kr1C18 → netECA18[Keys@test4Data9kr1C18, {"TopProbabilities", 2}]]
```

Out[•]=


{ → 102 484 955 339 910 707 201 065 → {4 → 2.85292 × 10^-12, 3 → 1.},

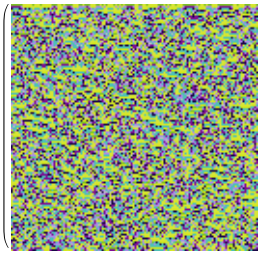

→ 225 104 493 515 167 213 968 116 → {4 → 2.59132 × 10^-19, 3 → 1.},


→ 82 955 736 870 484 114 072 206 → {4 → 7.69447 × 10^-10, 3 → 1.},

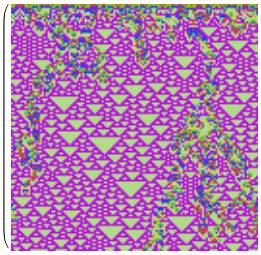


→ 671 885 429 563 685 913 440 220 →

{3 → 0.0000324644, 4 → 0.999968},

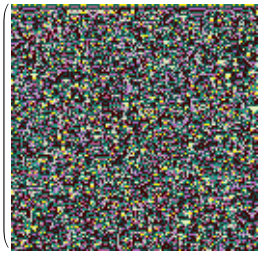


→ 319 540 285 313 900 469 182 543 → {4 → 1.25701 × 10^-7, 3 → 1.},

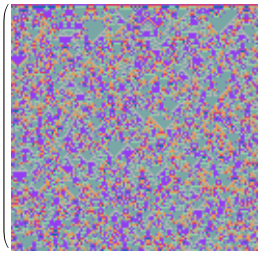


→ 472 683 159 387 864 865 560 932 →

{4 → 0.0000136606, 3 → 0.999986},



→ 522 719 371 598 196 985 234 941 → {4 → 5.12875 × 10^-11, 3 → 1.},



→ 135 699 531 967 322 696 819 064 → {4 → 4.81907 × 10^-12, 3 → 1.}}

Network XIX - Four convolutions, dropout on linear only, BatchNorm, MaxPool

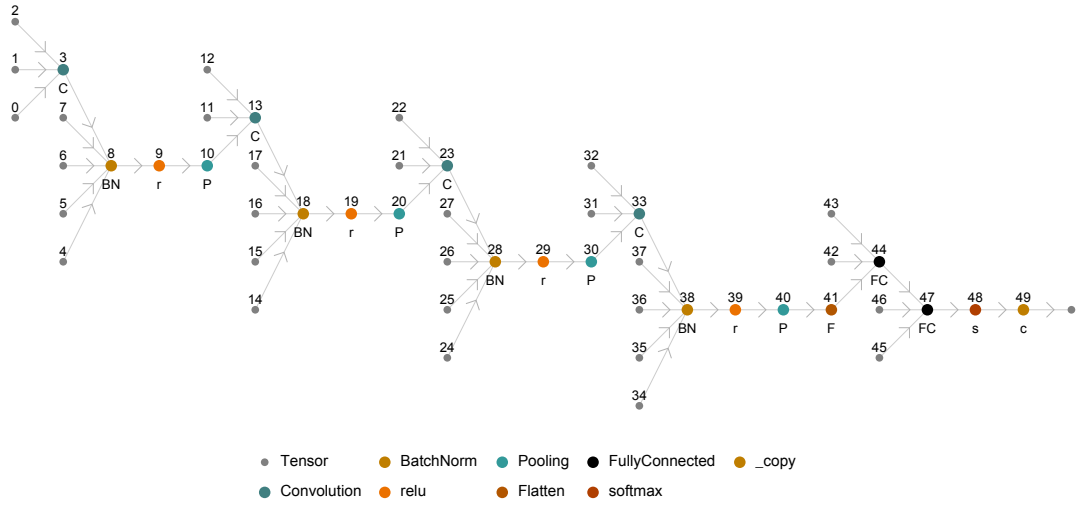
In[•]:=
```
netECA19 = netElevenCC1024drop[128, 128]
```

Out[•]= NetChain

	Input	image array (size: 3 × 128 × 128)
conv1	ConvolutionLayer	array (size: 48 × 126 × 126)
bat1	BatchNormalizationLayer	array (size: 48 × 126 × 126)
ramp1	Ramp	array (size: 48 × 126 × 126)
pooling1	PoolingLayer	array (size: 48 × 125 × 125)
conv2	ConvolutionLayer	array (size: 24 × 123 × 123)
bat2	BatchNormalizationLayer	array (size: 24 × 123 × 123)
ramp2	Ramp	array (size: 24 × 123 × 123)
pooling2	PoolingLayer	array (size: 24 × 122 × 122)
conv3	ConvolutionLayer	array (size: 24 × 120 × 120)
bat3	BatchNormalizationLayer	array (size: 24 × 120 × 120)
ramp3	Ramp	array (size: 24 × 120 × 120)
pooling3	PoolingLayer	array (size: 24 × 119 × 119)
conv4	ConvolutionLayer	array (size: 12 × 117 × 117)
bat4	BatchNormalizationLayer	array (size: 12 × 117 × 117)
ramp4	Ramp	array (size: 12 × 117 × 117)
pooling4	PoolingLayer	array (size: 12 × 116 × 116)
flatten	FlattenLayer	vector (size: 161472)
linear	LinearLayer	vector (size: 1024)
drop2	DropoutLayer	vector (size: 1024)
linear2	LinearLayer	vector (size: 4)
softmax	SoftmaxLayer	vector (size: 4)
	Output	class

In[•]:=
```
NetInformation[netECA19, "MXNetNodeGraphPlot"]
```

Out[•]=



In[•]:=
```
NetInformation[netECA19, "SummaryGraphic"]
```

Out[•]=

In[•]:=
```
dataECA19 = dataC[128, 128, 16 384];
```

In[•]:=
```
dataTotalistic2BigC19 = genData2r2C[128, 128, 4096];
```

In[•]:=
```
dataTotalistic3BigC19 = data3T2C[128, 128, 4096];
```

In[•]:=
```
dataTotalistic4BigC19 = data4TC[128, 128, 4096];
```

In[•]:=
```
dataTotalistic5BigC19 = genData5TCC[128, 128, 16 384];
```

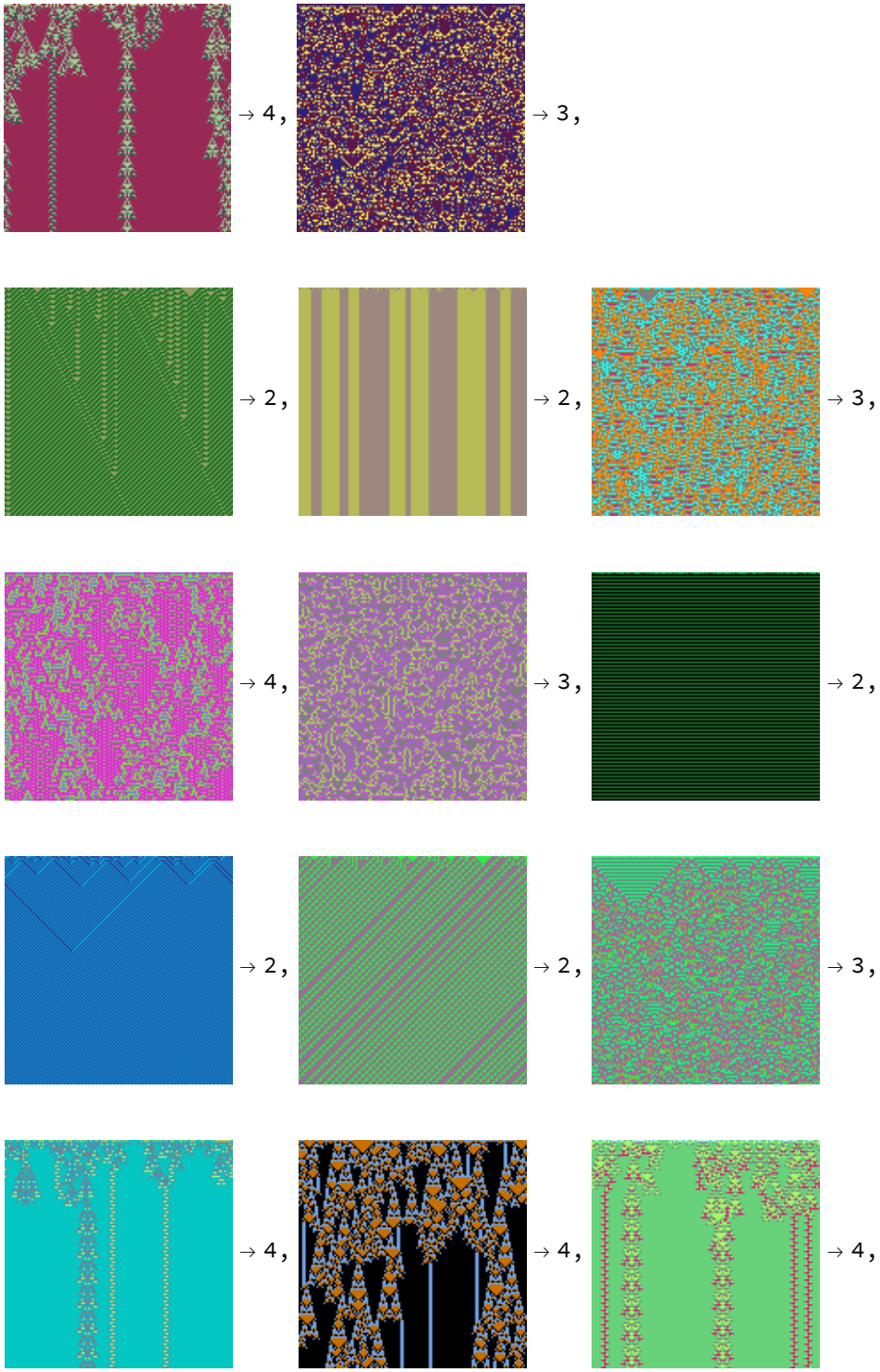
In[•]:=
```
fullTrainingBigC19 = Join[dataECA19, dataTotalistic2BigC19,
    dataTotalistic3BigC19, dataTotalistic4BigC19, dataTotalistic5BigC19];
```

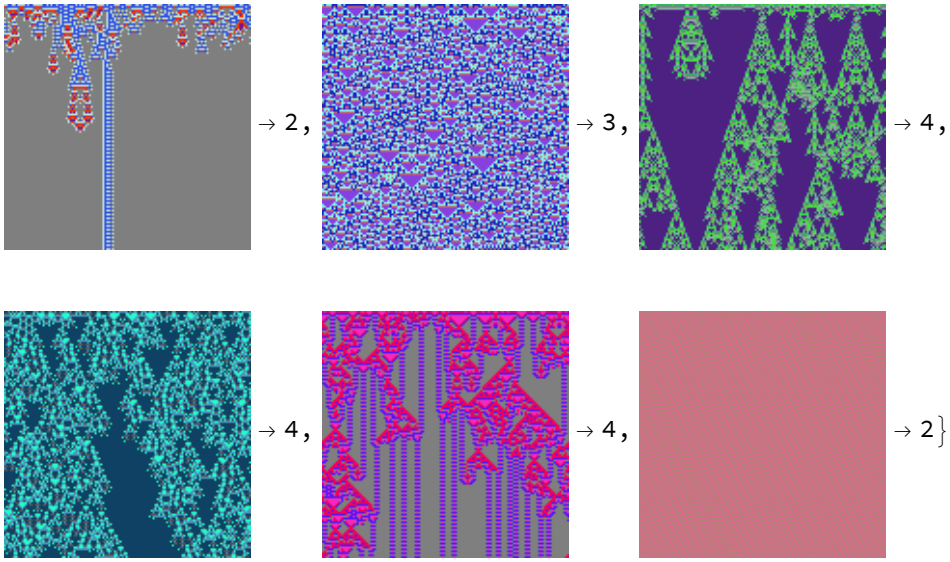
In[•]:= `Length[fullTrainingBigC19]`

Out[•]= 90 112

In[•]:= `RandomSample[fullTrainingBigC19, 20]`

Out[•]=





In[•]:=
```
dir = SetDirectory[NotebookDirectory[]]
```
Out[•]= /home/esilverman/Documents

In[•]:=
```
netECA19 = NetTrain[netECA19, fullTrainingBigC19,
  MaxTrainingRounds → 200, BatchSize → 256, TargetDevice → "GPU",
  TrainingProgressCheckpointing → {"Directory", dir}]
```

Generate test data for Network XIX (200 epochs)

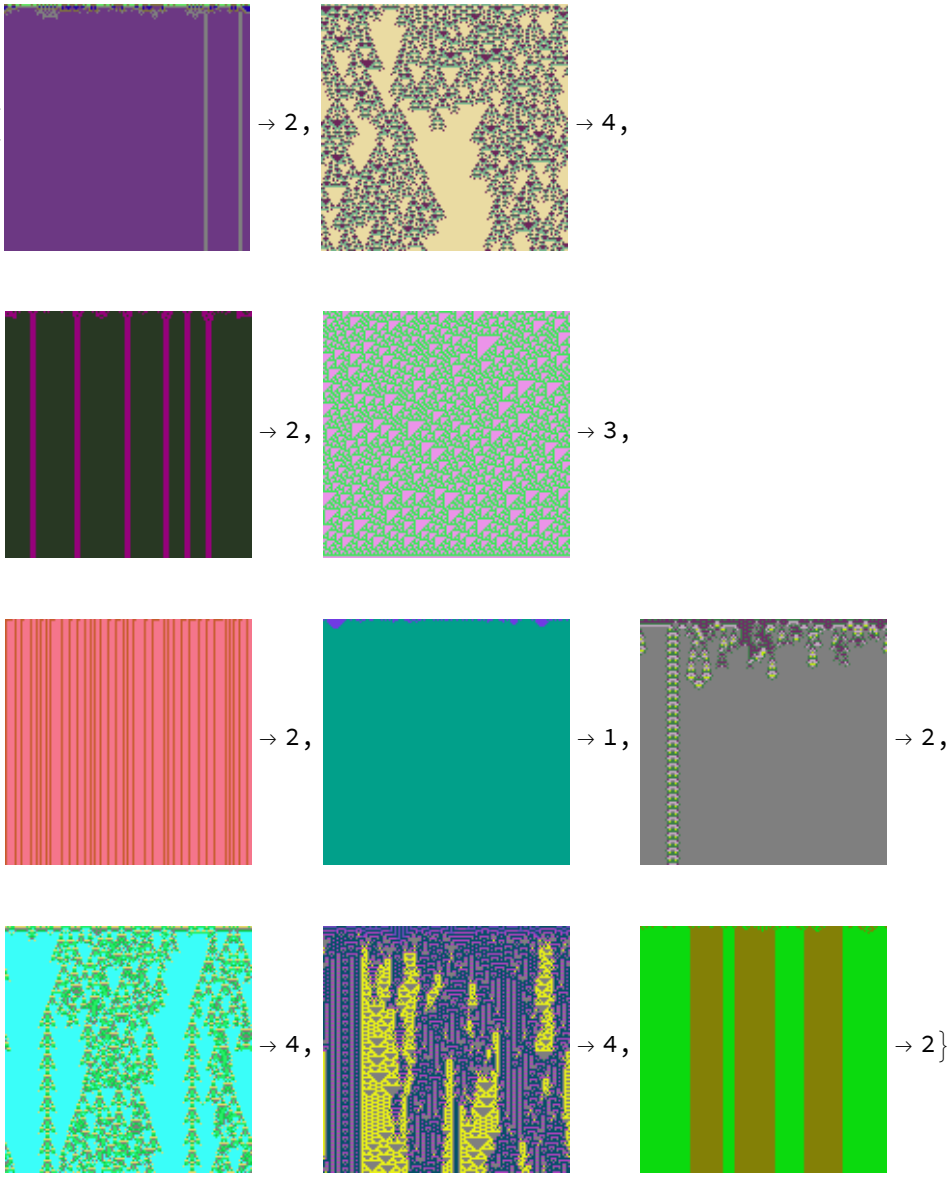
In[71]:=
```
dir = SetDirectory[NotebookDirectory[]]
```
Out[71]= /Users/thorsilver/Downloads/Wolfram notebooks

In[72]:=
```
netECA19 = Import["netECA19-r200.wlnet"]
```
Out[72]= NetChain[Input port: image; Output port: class; Number of layers: 21]

In[63]:=
```
testDataECABigC = dataC[128, 128, 1024];
testData2TBigC = genData2r2C[128, 128, 1024];
testData3TBigC = data3T2C[128, 128, 1024];
testData4TBigC = data4TC[128, 128, 1024];
testData5TBigC = genData5TCC[128, 128, 1024];
fullTestSetBigC = Join[testDataECABigC,
   testData2TBigC, testData3TBigC, testData4TBigC, testData5TBigC];
Length[fullTestSetBigC]
```
Out[69]= 10 240

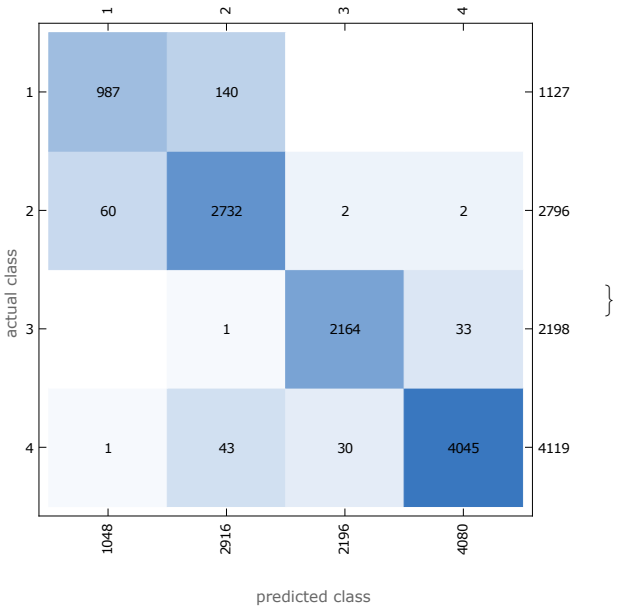
In[70]:=
```
RandomSample[fullTestSetBigC, 10]
```

Out[70]=



In[73]:=
```
NetMeasurements[netECA19, fullTestSetBigC,
 {"Accuracy", "Precision", "ConfusionMatrixPlot"}]
```

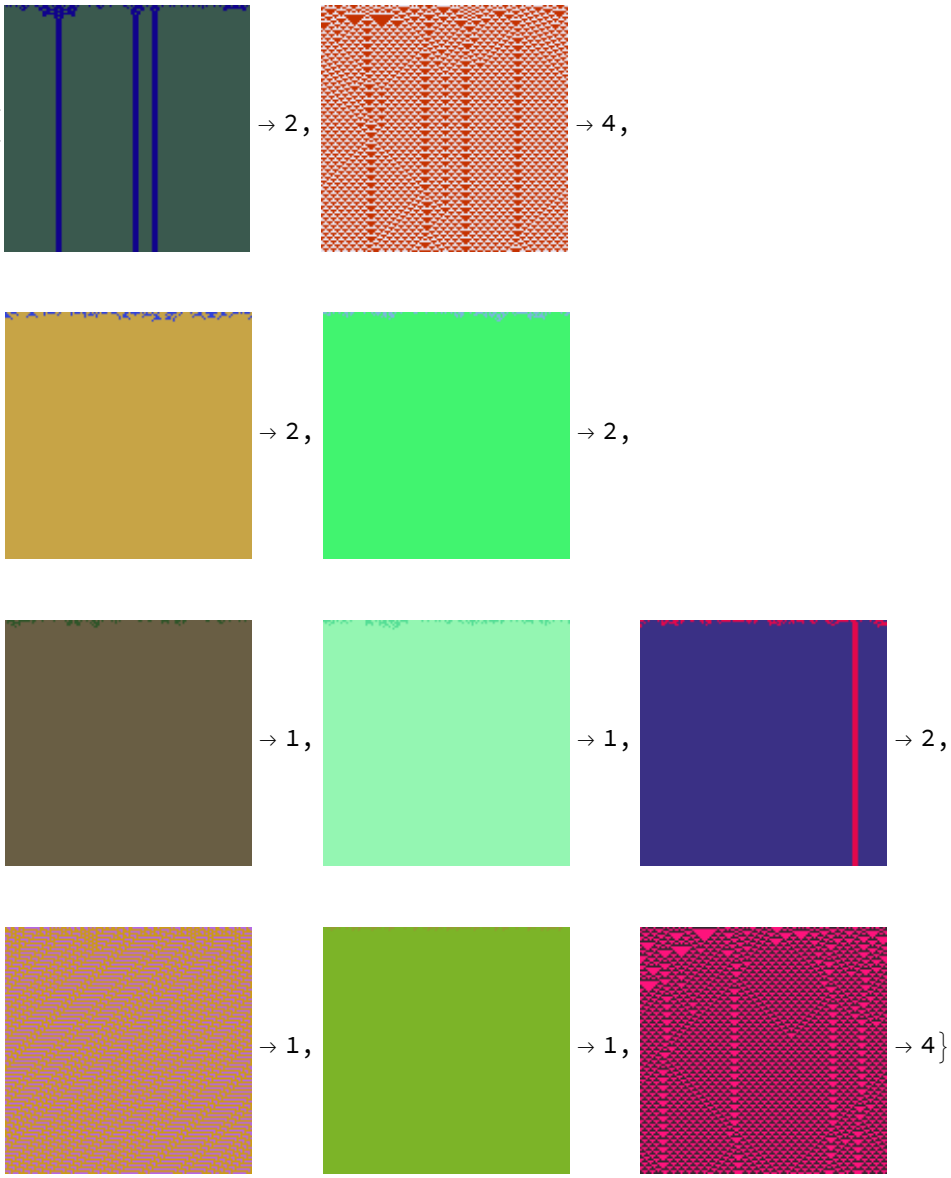
Out[73]=
```
{0.969531, ⟨|1 → 0.941794, 2 → 0.9369, 3 → 0.985428, 4 → 0.991422|⟩,
```



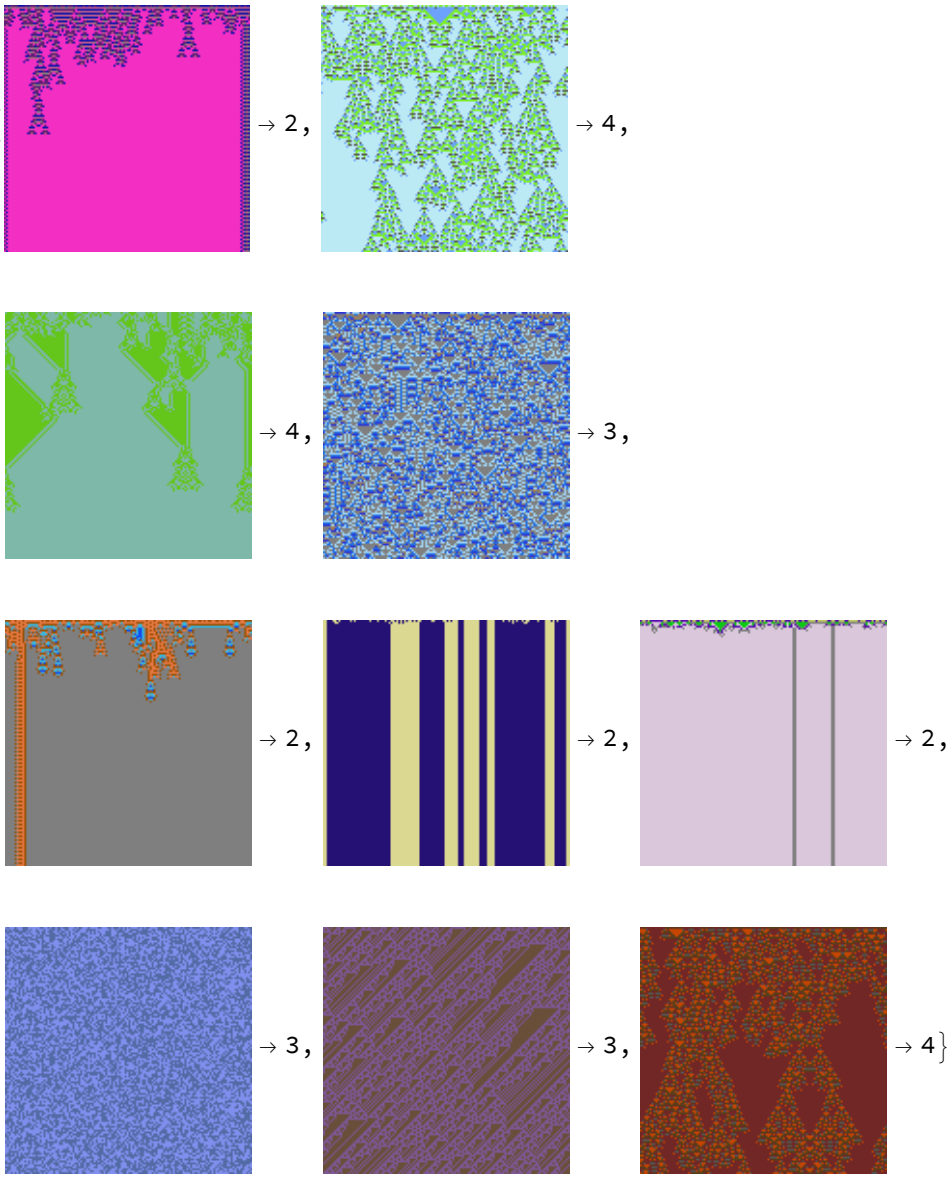

```
}
```

In[74]:=
```
entropyImagesBigC = RandomSample[Keys[fullTestSetBigC], 500];
entropiesBigC = netECA19[entropyImagesBigC, "Entropy"];
highEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, -10]]];
lowEntBigC = entropyImagesBigC[[Ordering[entropiesBigC, 10]]];
Thread[highEntBigC → netECA19[highEntBigC]]
Thread[lowEntBigC → netECA19[lowEntBigC]]
```

Out[78]=



Out[79]=

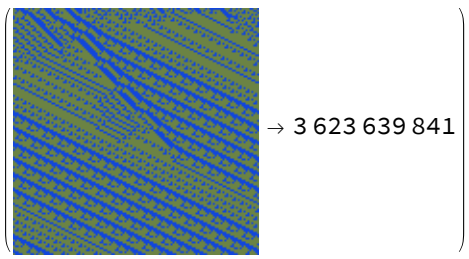


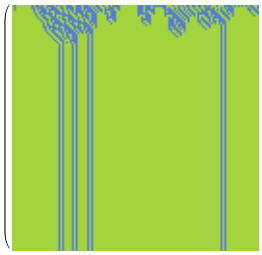
Testing Network XIX (200 epochs) on unseen CA rule spaces

2-colour non-totalistic, range 2

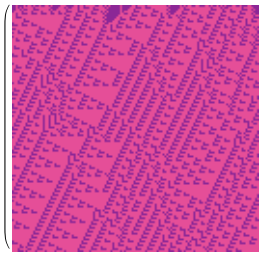
In[84]:=
```
test4Data2kr2C19 = datak2r2C[128, 128, 8];
Thread[
 test4Data2kr2C19 → netECA19[Keys@test4Data2kr2C19, {"TopProbabilities", 2}]]
```

Out[85]=



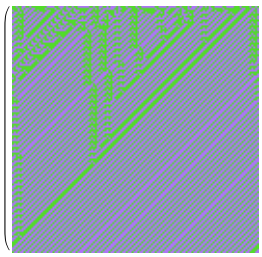


$\to 4\,204\,902\,033 \to \{4 \to 2.56823 \times 10^{-8}, 2 \to 1.\},$

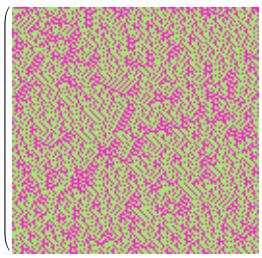


$\to 3\,766\,586\,648 \to \{1 \to 0., 3 \to 1.\},$

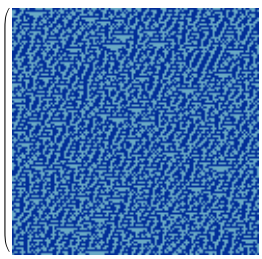
$\to 3\,083\,711\,710 \to \{4 \to 2.17708 \times 10^{-25}, 3 \to 1.\},$



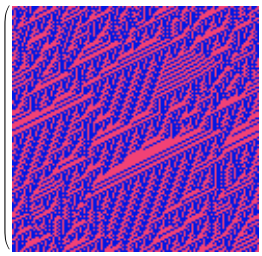
$\to 3\,912\,062\,127 \to \{1 \to 0., 2 \to 1.\},$



$\to 3\,127\,103\,417 \to \{1 \to 0., 3 \to 1.\},$



$\to 1\,368\,223\,734 \to \{3 \to 0.0375692, 4 \to 0.962431\},$



→ 1 157 293 582 → {4 → 0.253713, 3 → 0.746287}

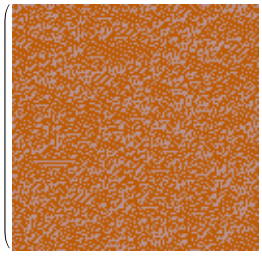
2-colour non-totalistic, range 3

In[86]:=
```
test4Data2kr3C19 = datak2r3NT[128, 128, 8];
Thread[
 test4Data2kr3C19 → netECA19[Keys@test4Data2kr3C19, {"TopProbabilities", 2}]]
```

Out[87]=

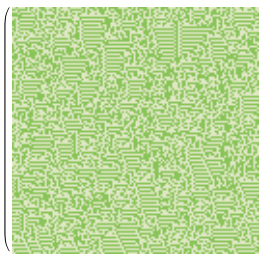
→ 124 905 465 127 170 717 525 549 371 999 495 851 185 →

$\{4 \to 4.25787 \times 10^{-22}, 3 \to 1.\}$,



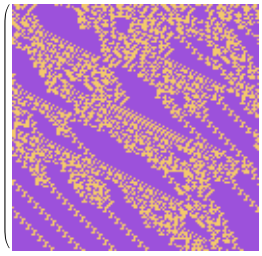
→ 64 150 751 993 555 644 365 500 719 311 625 036 355 →

$\{4 \to 3.40968 \times 10^{-31}, 3 \to 1.\}$,



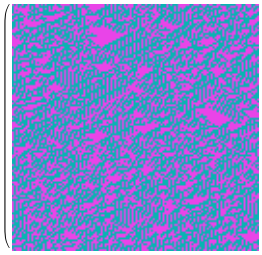
→ 36 728 299 501 322 596 356 207 863 519 173 249 151 →

$\{4 \to 1.92235 \times 10^{-12}, 3 \to 1.\}$,



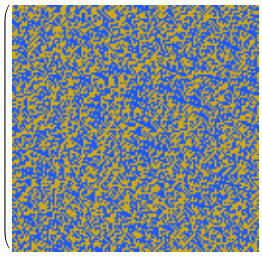
→ 323 119 304 778 780 202 562 738 468 472 713 800 353 →

$$\{3 \to 0.190559,\ 4 \to 0.809441\},$$



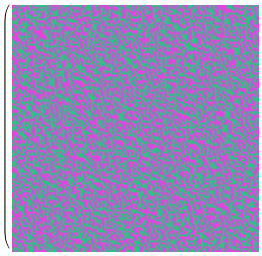
$$\to 176\,137\,957\,070\,216\,127\,711\,947\,686\,257\,562\,998\,744 \to$$

$$\{1 \to 0.,\ 3 \to 1.\},$$



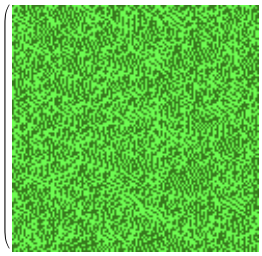
$$\to 66\,657\,172\,551\,850\,916\,438\,827\,226\,271\,776\,823\,681 \to$$

$$\{4 \to 9.37229 \times 10^{-18},\ 3 \to 1.\},$$



$$\to 95\,305\,147\,057\,683\,925\,587\,325\,090\,943\,101\,523\,205 \to$$

$$\{4 \to 1.7544 \times 10^{-26},\ 3 \to 1.\},$$

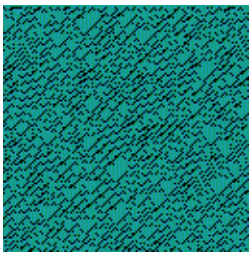


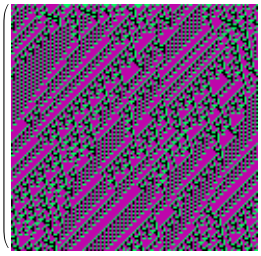
$$\to 75\,507\,431\,845\,018\,814\,437\,187\,840\,734\,694\,338\,361 \to$$

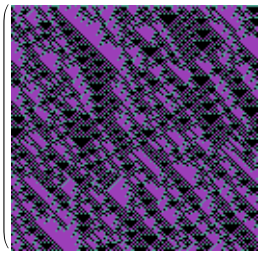
$$\{4 \to 1.14088 \times 10^{-28},\ 3 \to 1.\}\}$$

3-colour non-totalistic, range 1

In[90]:=
```
test4Data3kr1C19 = datak3r1NT[128, 128, 8];
Thread[
 test4Data3kr1C19 → netECA19[Keys@test4Data3kr1C19, {"TopProbabilities", 2}]]
```

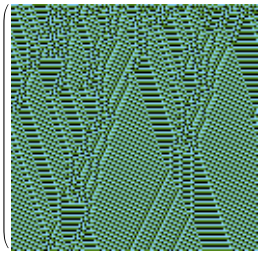
Out[91]= {  → 903 740 772 813 → {4 → 1.43387 × 10^-14, 3 → 1.},

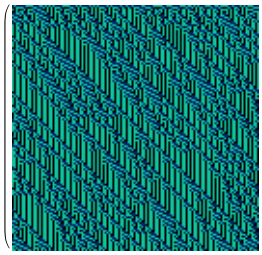
 → 4 969 181 144 217 → {2 → 0.0805151, 4 → 0.919485},

 → 7 038 367 528 689 → {3 → 8.64922 × 10^-26, 4 → 1.},

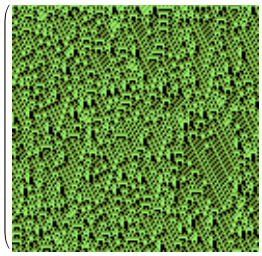
 → 432 813 174 387 → {4 → 1.4013 × 10^-45, 2 → 1.},

 → 2 083 475 355 420 → {4 → 1.38076 × 10^-8, 3 → 1.},

 → 966 244 316 659 → {4 → 8.30269 × 10^-33, 3 → 1.},



→ 2 855 715 719 711 → {1 → 0., 3 → 1.},

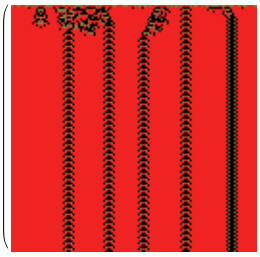


→ 2 262 027 167 458 → {4 → 9.07924 × 10^-22, 3 → 1.}}

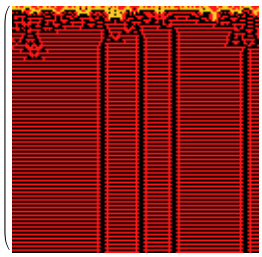
3-colour totalistic, range 2

In[100]:=
```
test4Data3kr2C19 = datak3r2C[128, 128, 8];
Thread[
 test4Data3kr2C19 → netECA19[Keys@test4Data3kr2C19, {"TopProbabilities", 2}]]
```

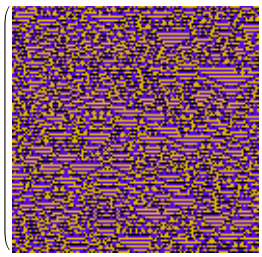
Out[101]=



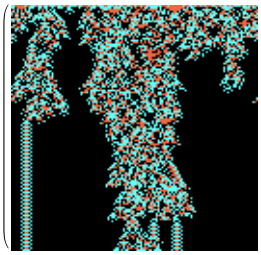
→ 44 637 → {1 → 0., 4 → 1.},



→ 97 532 → {1 → 0.0136907, 2 → 0.985288},

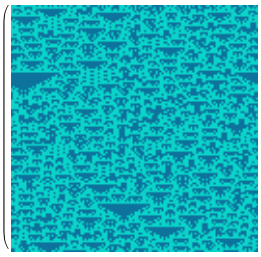


→ 81 718 → {4 → 2.22072 × 10^-29, 3 → 1.},

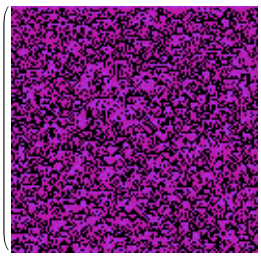


→ 168 849 → {1 → 0., 4 → 1.},

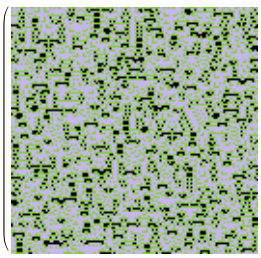
→ 169 937 → {2 → 0.0000493435, 1 → 0.999913},



→ 172 884 → {4 → 0.0000281311, 3 → 0.999972},



→ 76 127 → $\{4 \to 1.65065 \times 10^{-10}, 3 \to 1.\}$,

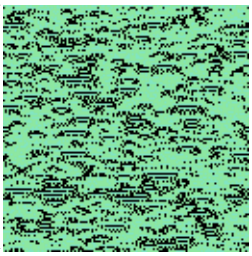


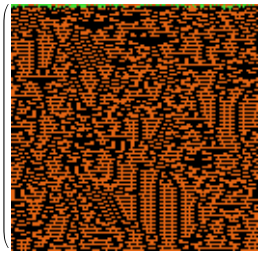
→ 72 457 → {3 → 0.0406162, 4 → 0.959384}}

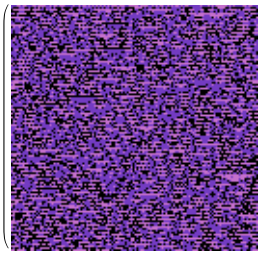
3-colour totalistic, range 3

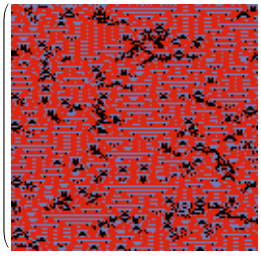
In[104]:=
```
test4Data3kr3C19 = datak3r3C[128, 128, 8];
Thread[
 test4Data3kr3C19 → netECA19[Keys@test4Data3kr3C19, {"TopProbabilities", 2}]]
```

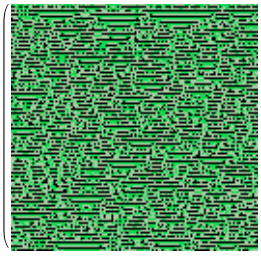
Out[105]= {

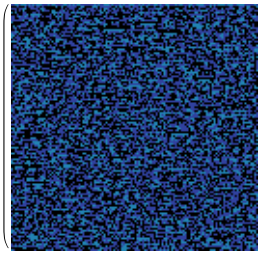
 → 5 332 402 → {1 → 0., 3 → 1.},

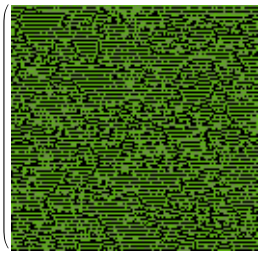
 → 12 215 348 → {3 → 0.0215091, 4 → 0.978491},

 → 5 882 266 → $\left\{4 \to 7.74599 \times 10^{-10}, 3 \to 1.\right\}$,

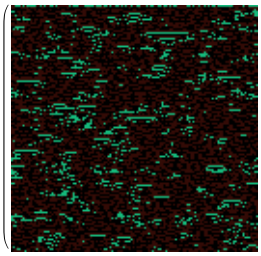
 → 3 262 519 → {1 → 0., 3 → 1.},

 → 4 981 094 → {4 → 0.000228014, 3 → 0.999772},

 → 9 082 439 → $\left\{4 \to 1.88074 \times 10^{-13}, 3 \to 1.\right\}$,



→ 1 672 559 → {3 → 0.0000689613, 4 → 0.999931},

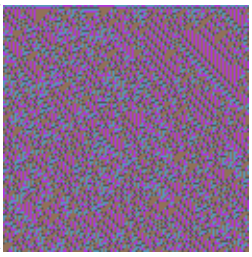


→ 4 454 413 → {3 → 0.152785, 4 → 0.847215}}

4-colour non-totalistic, range 1

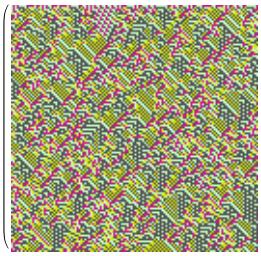
In[110]:=
```
test4Data4kr1C19 = datak4r1NT[128, 128, 8];
Thread[
 test4Data4kr1C19 → netECA19[Keys@test4Data4kr1C19, {"TopProbabilities", 2}]]
```

Out[111]=



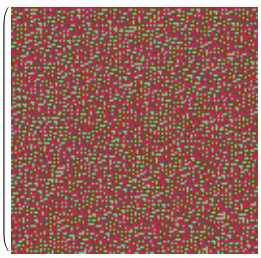
→ 268 480 064 929 651 762 891 007 015 829 128 083 689 →

{4 → 5.90905 × 10^-31, 3 → 1.},



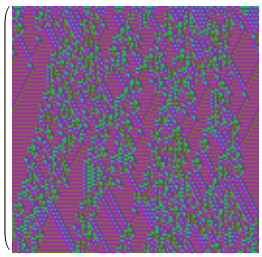
→ 309 415 291 386 320 905 513 458 675 451 823 606 210 →

{3 → 0.0527879, 4 → 0.947212},



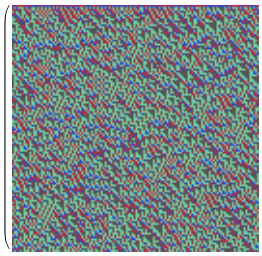
→ 30 989 344 170 865 628 249 558 072 247 841 941 742 →

{4 → 1.13198 × 10^-13, 3 → 1.},



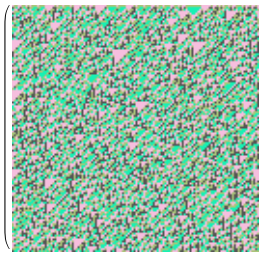
→ 38 159 113 987 244 829 576 355 750 648 069 816 463 →

$\{3 \to 5.90041 \times 10^{-36}, 4 \to 1.\}$,



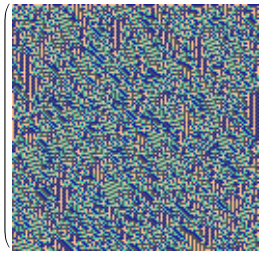
→ 249 183 157 890 630 189 577 220 606 861 906 191 102 →

$\{4 \to 5.20515 \times 10^{-10}, 3 \to 1.\}$,



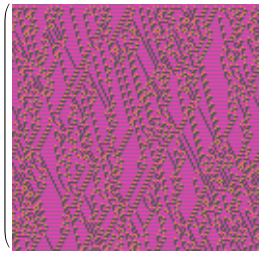
→ 303 528 074 844 669 290 852 560 133 934 740 411 631 →

$\{3 \to 0.0369437, 4 \to 0.963056\}$,



→ 86 045 152 578 514 755 153 037 573 764 695 519 542 →

$\{4 \to 9.68725 \times 10^{-27}, 3 \to 1.\}$,



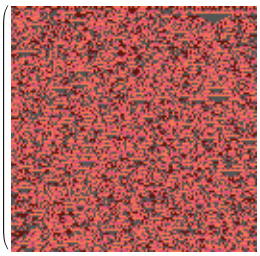
→ 35 725 484 667 282 961 631 098 969 929 047 786 325 →

$\{3 \to 2.96151 \times 10^{-29}, 4 \to 1.\}\}$

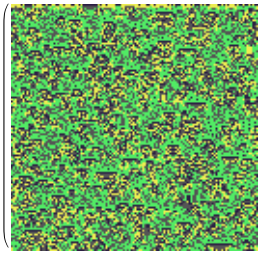
4-colour totalistic, range 2

In[112]:=
```
test4Data4kr2C19 = datak4r2C[128, 128, 8];
Thread[
 test4Data4kr2C19 → netECA19[Keys@test4Data4kr2C19, {"TopProbabilities", 2}]]
```

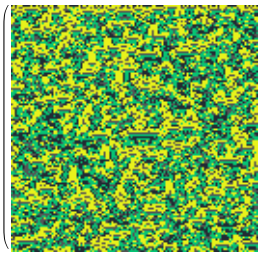
Out[113]=



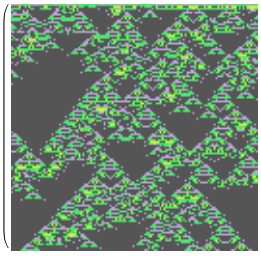
→ 3 039 279 908 → $\{4 \to 1.99769 \times 10^{-22}, 3 \to 1.\}$,



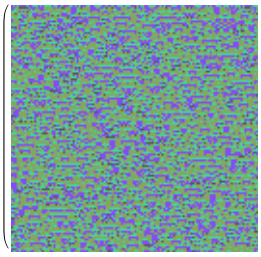
→ 1 004 857 722 → $\{4 \to 2.69276 \times 10^{-14}, 3 \to 1.\}$,



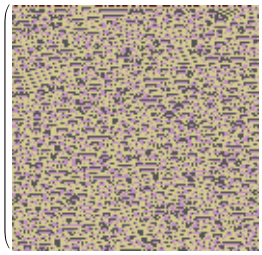
→ 1 136 086 050 → $\{4 \to 5.1036 \times 10^{-14}, 3 \to 1.\}$,



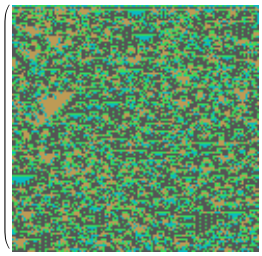
→ 3 492 358 882 → $\{3 \to 1.56014 \times 10^{-7}, 4 \to 1.\}$,



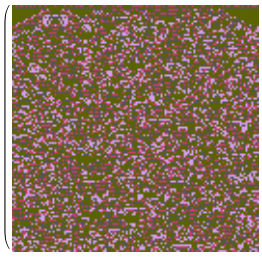
→ 1 069 866 717 → $\{4 \to 8.91689 \times 10^{-21}, 3 \to 1.\}$,



$\to 171\,122\,738 \to \{4 \to 2.21848 \times 10^{-11}, 3 \to 1.\},$



$\to 3\,452\,577\,709 \to \{4 \to 1.17042 \times 10^{-13}, 3 \to 1.\},$

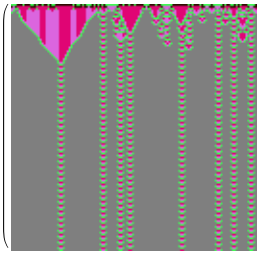


$\to 701\,805\,990 \to \{4 \to 2.21188 \times 10^{-16}, 3 \to 1.\}\}$

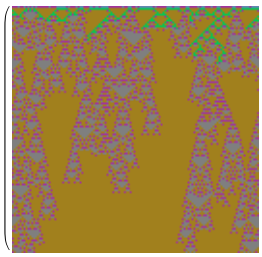
5-colour totalistic, range 1

In[116]:=
```
test4Data5kr1C19 = data5T2C[8, 128, 128];
Thread[
 test4Data5kr1C19 → netECA19[Keys@test4Data5kr1C19, {"TopProbabilities", 2}]]
```

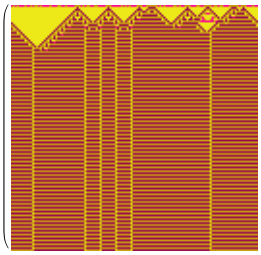
Out[117]=



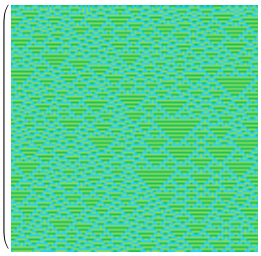
$\{\to 1\,207\,540\,399 \to \{4 \to 2.97016 \times 10^{-21}, 2 \to 1.\},$



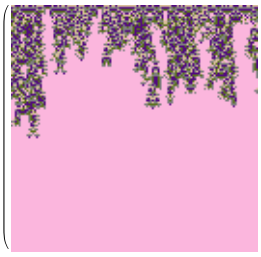
$\to 1\,142\,383\,118 \to \{1 \to 0., 4 \to 1.\},$



→ 1 123 443 123 → {4 → 0.0000133564, 2 → 0.999987},

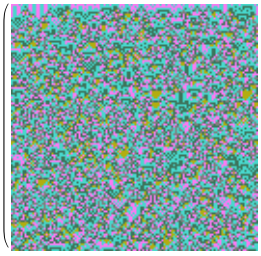


→ 179 147 268 → {3 → 0.00253984, 4 → 0.99746},

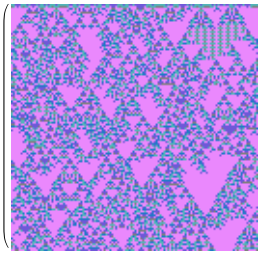


→ 1 070 088 188 → $\{4 \to 5.16433 \times 10^{-17}, 2 \to 1.\}$,

→ 839 709 526 → $\{1 \to 1.99965 \times 10^{-42}, 2 \to 1.\}$,



→ 1 029 145 401 → $\{4 \to 4.63463 \times 10^{-18}, 3 \to 1.\}$,

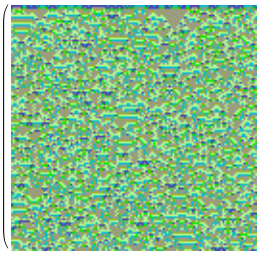


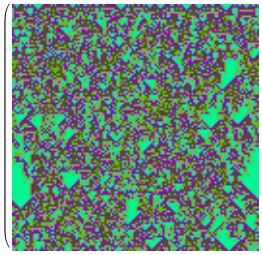
→ 153 105 290 → $\{3 \to 4.82742 \times 10^{-35}, 4 \to 1.\}\}$

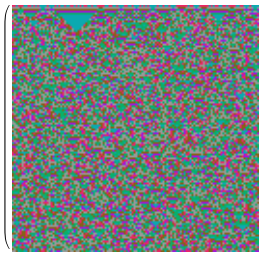
6-colour totalistic, range 1

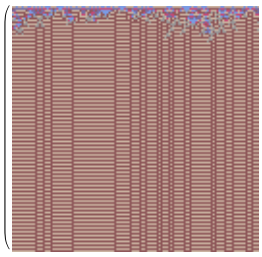
In[124]:=
```
test4Data6kr1C19 = data6TC[8, 128, 128];
Thread[
 test4Data6kr1C19 → netECA19[Keys@test4Data6kr1C19, {"TopProbabilities", 2}]]
```

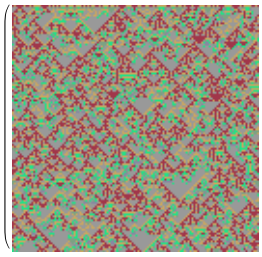
Out[125]=

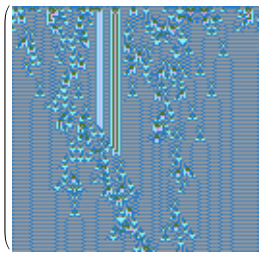

→ 521 151 757 166 → $\{4 \to 4.2538 \times 10^{-27}, 3 \to 1.\}$,


→ 1 148 948 615 051 → $\{3 \to 1.05684 \times 10^{-11}, 4 \to 1.\}$,

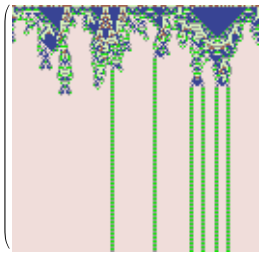

→ 1 701 138 861 521 → $\{3 \to 0.344279, 4 \to 0.655721\}$,


→ 772 044 852 372 → $\{4 \to 3.00861 \times 10^{-22}, 2 \to 1.\}$,


→ 401 641 356 701 → $\{4 \to 1.64612 \times 10^{-16}, 3 \to 1.\}$,



→ 1 317 230 504 887 → $\{3 \to 7.00649 \times 10^{-45}, 4 \to 1.\}$,



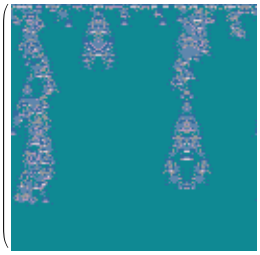
→ 688 870 202 959 → $\{2 \to 4.08491 \times 10^{-13}, 4 \to 1.\}$,

→ 2 362 168 351 069 → $\{2 \to 9.19252 \times 10^{-43}, 4 \to 1.\}\}$

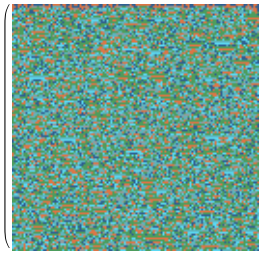
6-colour totalistic, range 2

In[134]:=
```
test4Data6kr2C19 = data6T2C[8, 128, 128];
Thread[
 test4Data6kr2C19 → netECA19[Keys@test4Data6kr2C19, {"TopProbabilities", 2}]]
```

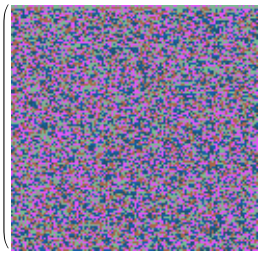
Out[135]= $\{$



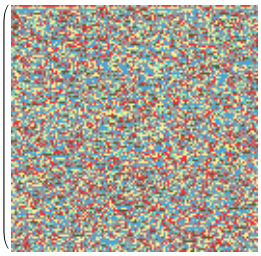
→ 148 490 913 881 245 616 342 → $\{3 \to 6.33961 \times 10^{-15}, 4 \to 1.\}$,



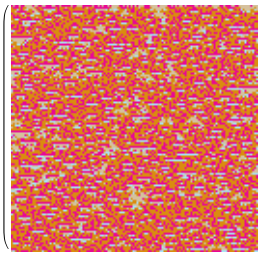
→ 137 813 202 347 051 710 725 → $\{4 \to 2.24399 \times 10^{-27}, 3 \to 1.\}$,



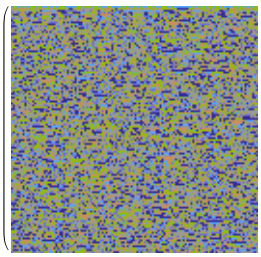
→ 145 612 570 579 789 266 485 → $\{4 \to 1.52405 \times 10^{-9}, 3 \to 1.\}$,



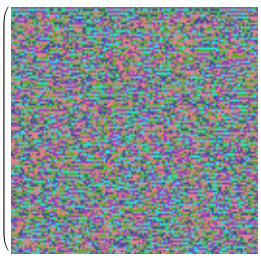
→ 57 362 919 586 594 306 710 → $\{4 \to 0.031388, 3 \to 0.968612\}$,



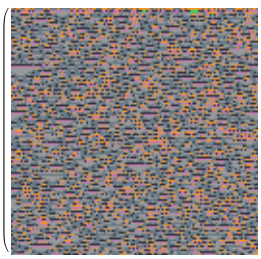
→ 24 770 952 214 224 040 296 → $\{4 \to 5.16516 \times 10^{-16}, 3 \to 1.\}$,



→ 143 600 862 017 240 236 453 → $\{4 \to 1.30214 \times 10^{-22}, 3 \to 1.\}$,



→ 160 410 817 633 450 677 074 → $\{4 \to 0.000231853, 3 \to 0.999768\}$,

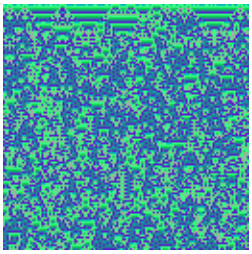


→ 99 035 735 849 117 353 433 → $\{4 \to 7.72208 \times 10^{-20}, 3 \to 1.\}\}$

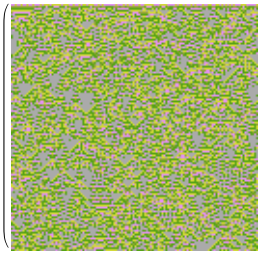
7-colour totalistic, range 1

In[140]:=
```
test4Data7kr1C19 = data7TC[8, 128, 128];
Thread[
 test4Data7kr1C19 → netECA19[Keys@test4Data7kr1C19, {"TopProbabilities", 2}]]
```

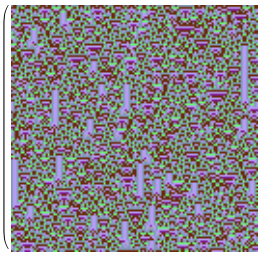
Out[141]=



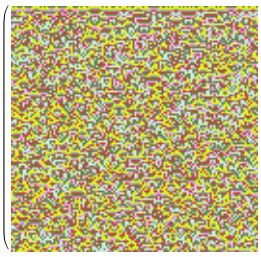
→ 7 905 962 486 151 833 → {4 → 0.000554173, 3 → 0.999446},



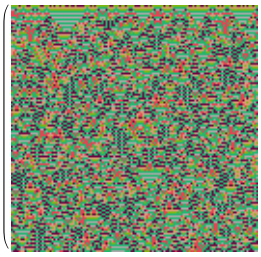
→ 5 986 825 348 569 542 → {4 → 0.0000562114, 3 → 0.999944},



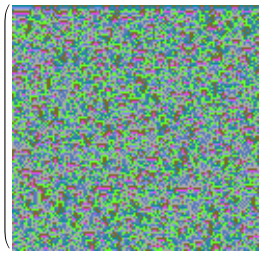
→ 5 160 779 372 988 604 → $\{3 \to 1.30743 \times 10^{-8}, 4 \to 1.\}$,



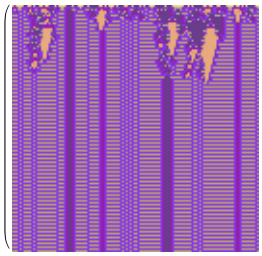
→ 2 668 104 076 298 035 → $\{4 \to 3.94844 \times 10^{-18}, 3 \to 1.\}$,



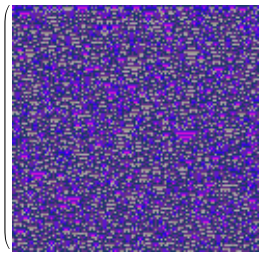
→ 3 691 759 700 407 743 → $\{4 \to 4.45377 \times 10^{-16}, 3 \to 1.\}$,



→ 1 440 812 301 139 250 → {4 → 2.17204 × 10^-16, 3 → 1.},



→ 10 929 419 536 918 414 → {4 → 0.0898063, 2 → 0.910194},

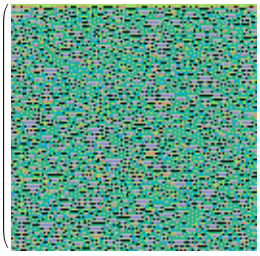


→ 870 299 002 890 078 → {4 → 2.68048 × 10^-10, 3 → 1.}}

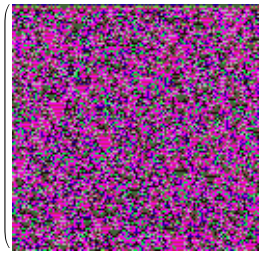
8-colour totalistic, range 1

In[142]:=
```
test4Data8kr1C19 = data8TC[8, 128, 128];
Thread[
 test4Data8kr1C19 → netECA19[Keys@test4Data8kr1C19, {"TopProbabilities", 2}]]
```

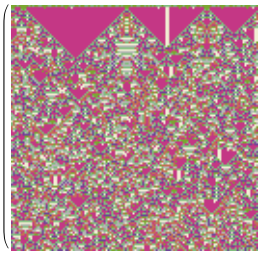
Out[143]=



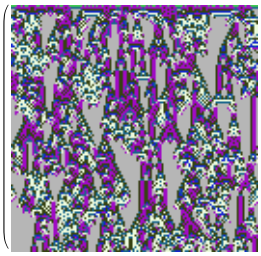
→ 59 125 043 292 911 533 831 → {4 → 2.29341 × 10^-24, 3 → 1.},



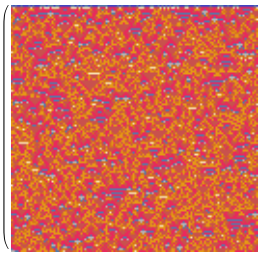
→ 42 327 489 577 905 146 096 → {4 → 2.26592 × 10^-16, 3 → 1.},



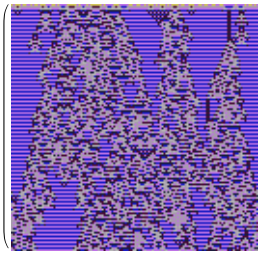
$\to 27\,493\,918\,164\,619\,079\,600 \to \{4 \to 1.41836 \times 10^{-22}, 3 \to 1.\},$



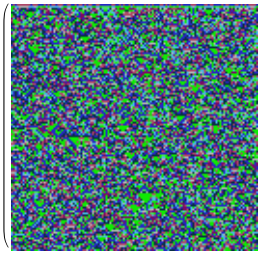
$\to 44\,604\,484\,385\,457\,579\,525 \to \{1 \to 0., 4 \to 1.\},$



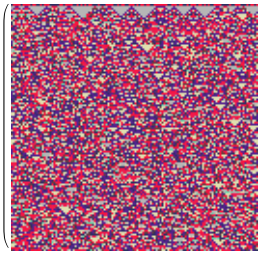
$\to 44\,601\,321\,771\,076\,613\,987 \to \{4 \to 7.78289 \times 10^{-25}, 3 \to 1.\},$



$\to 41\,129\,731\,740\,372\,203\,883 \to \{3 \to 0.274545, 4 \to 0.725455\},$



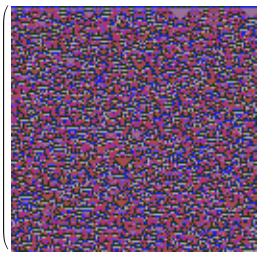
$\to 69\,557\,501\,891\,528\,005\,051 \to \{4 \to 5.60689 \times 10^{-12}, 3 \to 1.\},$



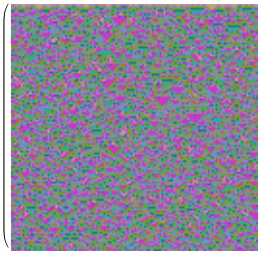
$\to 71\,754\,449\,283\,143\,194\,262 \to \{4 \to 2.72879 \times 10^{-13}, 3 \to 1.\}\}$

In[146]:=
```
test4Data8kr1C19 = data8TC[8, 128, 128];
Thread[
 test4Data8kr1C19 → netECA19[Keys@test4Data8kr1C19, {"TopProbabilities", 2}]]
```

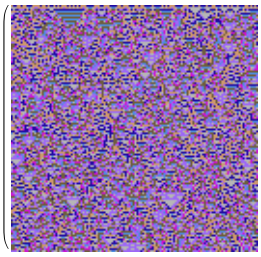
Out[147]=



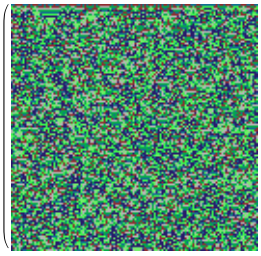
→ 30 958 781 818 328 214 442 → {4 → 4.62524 × 10^-15, 3 → 1.},



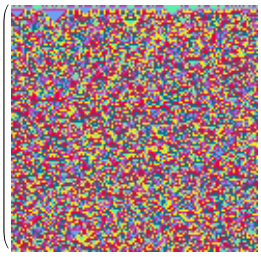
→ 61 018 914 870 782 867 384 → {4 → 1.13687 × 10^-12, 3 → 1.},



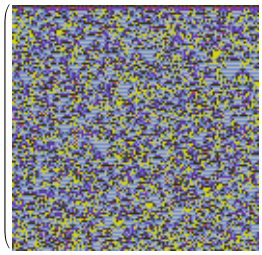
→ 20 705 257 985 378 094 677 → {4 → 1.82975 × 10^-19, 3 → 1.},



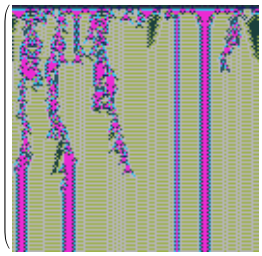
→ 43 941 374 463 684 638 030 → {4 → 1.04552 × 10^-6, 3 → 0.999999},



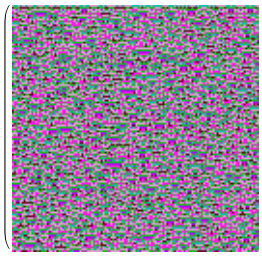
→ 3 024 227 929 898 264 848 → {4 → 1.85219 × 10^-8, 3 → 1.},



→ 17 487 862 603 567 426 913 → {4 → 3.05308 × 10^-7, 3 → 1.},



→ 63 093 631 381 744 169 828 → {2 → 1.26841 × 10^-29, 4 → 1.},

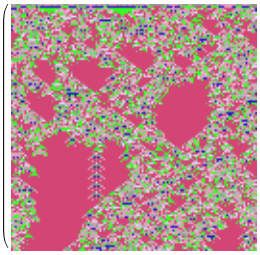


→ 27 830 330 837 012 619 129 → {4 → 0.126106, 3 → 0.873894}}

8-colour totalistic, range 2

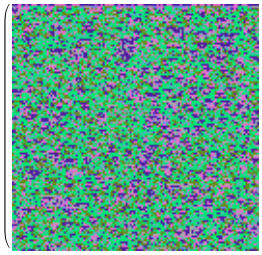
In[162]:=
```
test4Data8kr2C19 = data8T2C[8, 128, 128];
Thread[
 test4Data8kr2C19 → netECA19[Keys@test4Data8kr2C19, {"TopProbabilities", 2}]]
```

Out[163]=



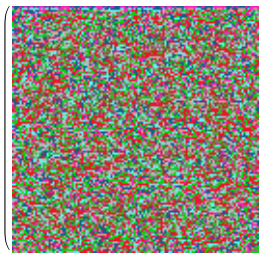
→ 147 951 460 881 093 444 119 820 865 699 524 →

{3 → 1.95996 × 10^-6, 4 → 0.999998},



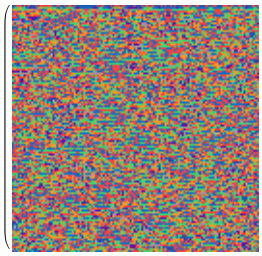
→ 119 355 423 761 325 445 881 228 685 558 134 →

{4 → 0.060776, 3 → 0.939224},



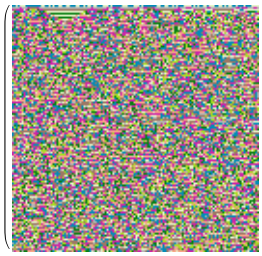
→ 307 982 756 305 321 800 462 830 043 829 803 →

$\{4 \to 2.91468 \times 10^{-9}, 3 \to 1.\}$,



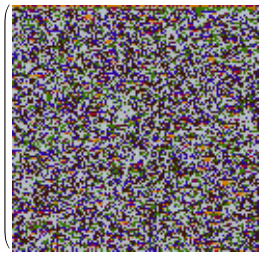
→ 62 874 465 515 649 272 486 967 493 933 559 →

$\{4 \to 5.81908 \times 10^{-7}, 3 \to 0.999999\}$,



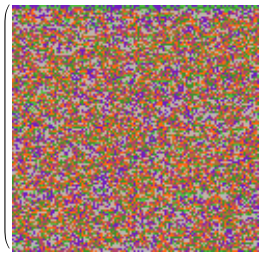
→ 65 948 684 565 606 780 569 516 519 912 636 →

$\{4 \to 0.0000545016, 3 \to 0.999946\}$,



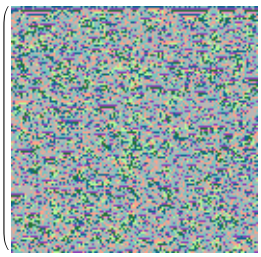
→ 181 374 136 488 855 143 429 706 946 971 289 →

$\{4 \to 2.66552 \times 10^{-19}, 3 \to 1.\}$,



→ 176 951 646 325 376 055 797 052 520 179 269 →

$\{4 \to 1.80483 \times 10^{-11}, 3 \to 1.\}$,



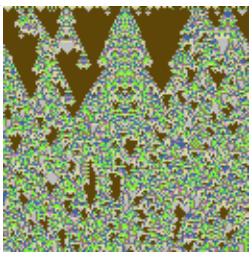
→ 223 691 650 274 434 738 686 390 233 580 833 →

$\{4 \to 1.5659 \times 10^{-25}, 3 \to 1.\}\}$

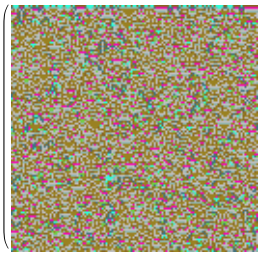
9-colour totalistic, range 1

In[164]:=
```
test4Data9kr1C19 = data9TC[8, 128, 128];
Thread[
 test4Data9kr1C19 → netECA19[Keys@test4Data9kr1C19, {"TopProbabilities", 2}]]
```

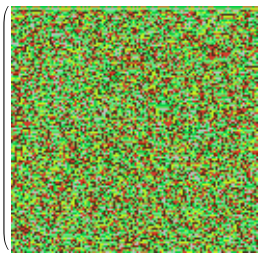
Out[165]=



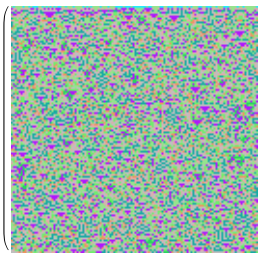
→ 650 813 664 375 243 924 798 654 → $\{3 \to 1.79014 \times 10^{-12}, 4 \to 1.\}$,



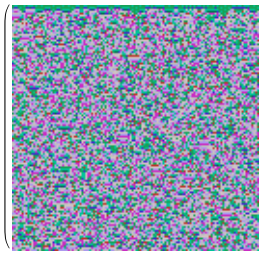
→ 693 038 569 142 680 517 501 061 → $\{4 \to 1.91095 \times 10^{-15}, 3 \to 1.\}$,



→ 172 075 759 297 755 102 243 593 → $\{4 \to 8.47525 \times 10^{-15}, 3 \to 1.\}$,

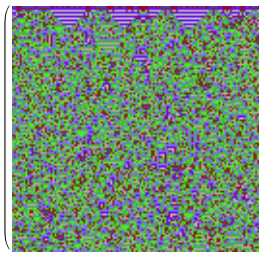


→ 635 936 007 119 328 418 474 377 → $\{4 \to 8.59589 \times 10^{-12}, 3 \to 1.\}$,

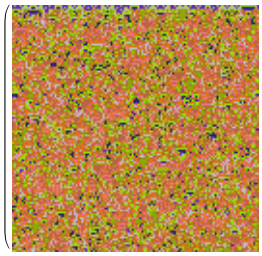


→ 83 078 033 797 966 507 654 335 →

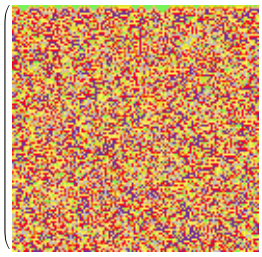
$\{4 \to 2.50512 \times 10^{-6}, 3 \to 0.999997\}$,



→ 61 694 440 956 086 220 642 257 → $\{4 \to 1.8296 \times 10^{-15}, 3 \to 1.\}$,



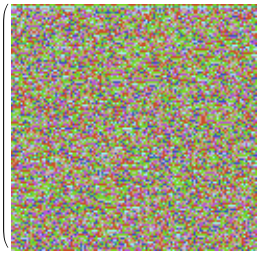
→ 19 805 866 291 496 747 949 388 → $\{4 \to 4.2757 \times 10^{-11}, 3 \to 1.\}$,



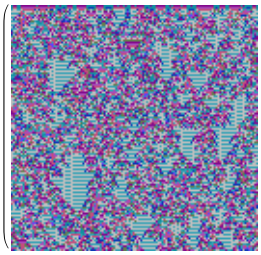
→ 117 792 334 074 770 391 492 414 → $\{4 \to 4.76414 \times 10^{-21}, 3 \to 1.\}\}$

In[168]:=
```
test4Data9kr1C19 = data9TC[8, 128, 128];
Thread[
 test4Data9kr1C19 → netECA19[Keys@test4Data9kr1C19, {"TopProbabilities", 2}]]
```

Out[169]=

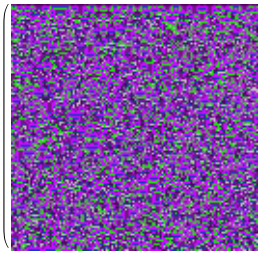


→ 345 366 264 162 505 652 483 033 → $\{4 \to 8.11519 \times 10^{-8}, 3 \to 1.\}$,

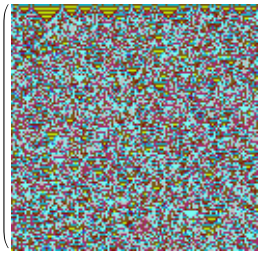


→ 169 035 156 573 517 225 784 083 →

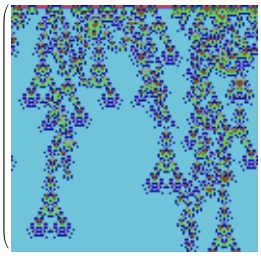
{4 → 0.000967143, 3 → 0.999033},



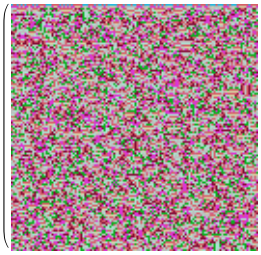
→ 241 423 372 275 813 570 992 926 → {4 → 1.72993 × 10^-11, 3 → 1.},



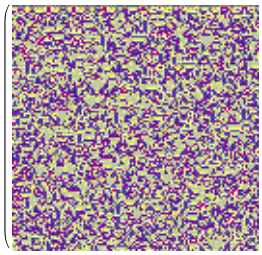
→ 323 997 218 462 529 363 923 161 → {4 → 7.27233 × 10^-16, 3 → 1.},

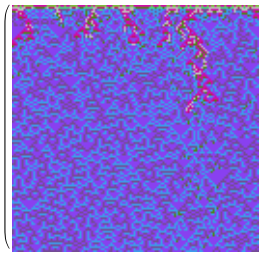


→ 274 602 130 627 677 155 314 032 → {1 → 0., 4 → 1.},



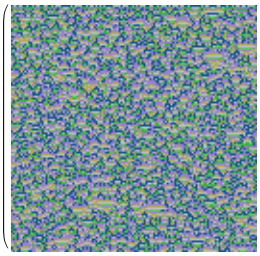
→ 538 007 856 396 749 781 700 396 → {4 → 1.82013 × 10^-20, 3 → 1.},

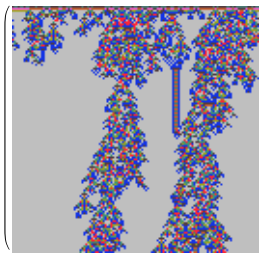

→ 282 255 417 383 452 533 668 794 → {4 → 1.74469 × 10^-12, 3 → 1.},

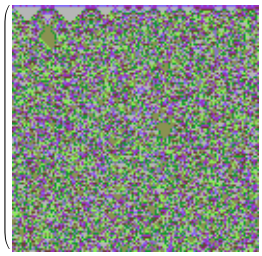

→ 386 779 672 558 013 182 448 702 → {4 → 1.71419 × 10^-17, 3 → 1.}}

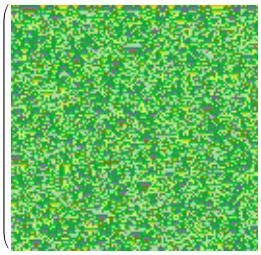
In[178]:=
```
test4Data9kr1C19 = data9TC[8, 128, 128];
Thread[
 test4Data9kr1C19 → netECA19[Keys@test4Data9kr1C19, {"TopProbabilities", 2}]]
```

Out[179]=

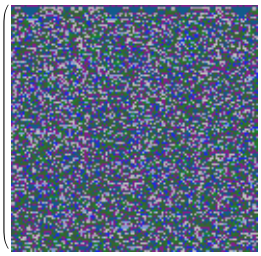

{ → 161 973 745 861 678 692 145 183 → {4 → 1.92323 × 10^-16, 3 → 1.},


→ 195 265 225 475 606 991 826 639 → {1 → 0., 4 → 1.},

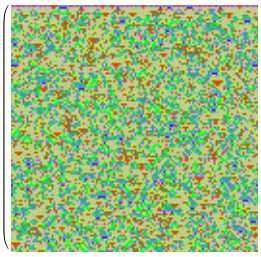

→ 229 976 304 993 680 042 622 116 → {4 → 1.13598 × 10^-14, 3 → 1.},



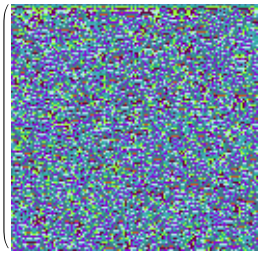
→ 45 546 192 831 416 331 168 463 → {4 → 1.78072 × 10^-8, 3 → 1.},



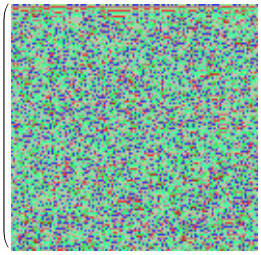
→ 271 317 841 721 163 552 341 788 → {4 → 5.28559 × 10^-9, 3 → 1.},



→ 386 796 588 960 959 381 307 104 → {4 → 0.00324702, 3 → 0.996753},



→ 13 757 000 133 048 760 792 605 → {4 → 0.00048392, 3 → 0.999516},



→ 148 054 017 088 260 077 744 039 → {4 → 9.52466 × 10^-14, 3 → 1.}}