Demo 2: Constructing Networks

Making graphs from CAs

Note: Double-click the grey brackets on the right hand side to expand or collapse cells!
A filled triangle indicates it is a collapsed cell.

Sometimes, it's fun to think about the world in terms of states and transitions between those states. From the previous demo, we see that CA are a great analogy for this. Let's explore these transitions a little bit further...

What if we want to know all the possible transitions between all possible states, we can do that! All we need to do it run a single time step for every possible state, to see where each of them goes. Then we can mush all the results together to get a full picture.

Here are all the possible states for a CA of width = 3:

In[•]:=
```
ics = Tuples[{0, 1}, 3]
```

Out[•]=
```
{{0, 0, 0}, {0, 0, 1}, {0, 1, 0}, {0, 1, 1}, {1, 0, 0}, {1, 0, 1}, {1, 1, 0}, {1, 1, 1}}
```

Now we want to run all these states in a CA.

In[•]:=
```
result = Table[CellularAutomaton[0, ic, 1], {ic, ics}]
```

Out[•]=
```
{{{0, 0, 0}, {0, 0, 0}}, {{0, 0, 1}, {0, 0, 0}},
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```

So, as you can see for all possible initial states it always goes to all 0's, since it is Rule 0.

And while we're at it, let's see these transitions under all possible rules. Let's do a double-loop! This Table function can have more than one variable to loop over. It will loop over the initial states, and then will loop that over all rules with this format:

In[•]:=
```
results = Table[CellularAutomaton[r, ic, 1], {r, 0, 255}, {ic, ics}]
```

Out[•]=
```
{{{{0, 0, 0}, {0, 0, 0}}, {{0, 0, 1}, {0, 0, 0}},
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```

We don't need to visualize these CAs. Instead, we want to visualize the transitions between states on a graph. Let's do this for one rule, Rule 0. I draw arrows between what states go to where from our results in the previous Table double-loop:

In[•]:=
```
results[[1]]
```

Out[•]=
```
{{{0, 0, 0}, {0, 0, 0}}, {{0, 0, 1}, {0, 0, 0}},
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```

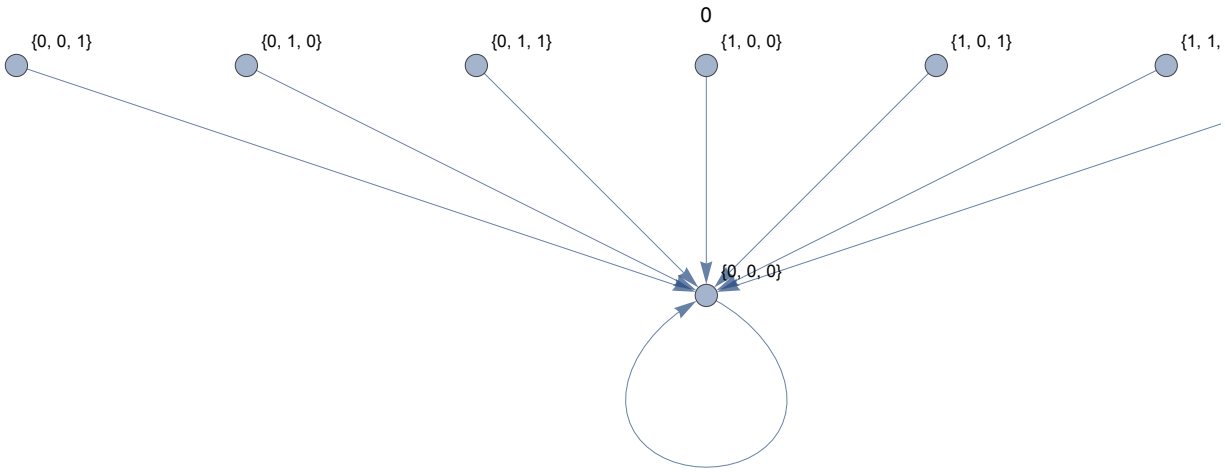
In[•]:=
```
Rule @@@ results[[1]]
```

Out[•]=
```
{{0, 0, 0} → {0, 0, 0}, {0, 0, 1} → {0, 0, 0}, {0, 1, 0} → {0, 0, 0}, {0, 1, 1} → {0, 0, 0},
 {1, 0, 0} → {0, 0, 0}, {1, 0, 1} → {0, 0, 0}, {1, 1, 0} → {0, 0, 0}, {1, 1, 1} → {0, 0, 0}}
```

If it is formatted with arrows this way, the Graph function can read this essentially as an edge list. That is basically a list of vertex1 -> (goes to) vertex2. Then it is easy to plot with Graph:

In[•]:=
```
Graph[Rule @@@ results[[1]], VertexLabels → "Name", PlotLabel → 0]
```

Out[•]=



You can do this with all the rules! We calculated the results for all the rules already, so simply select the rule you want and modify the above line. Remember, results[[1]] means Rule 0.

Bonus!

If you want to get really fancy, you can make your own Mathematica functions in addition to Table and Graph and Cellular Automata. Why would we want to do that? Well, what if we'd like to apply the arrows to ALL our CA results and then visualize them ALL on a graph? We would need to make a special function that calls both.

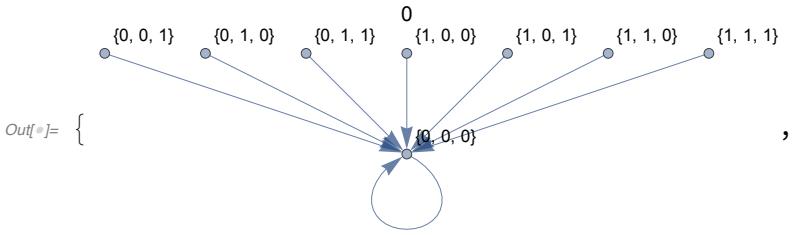
Let's call this function f, cause we're boring.
It takes in two variables, x and r. The first one x will be our big results Table. The second variable r will be the rule:

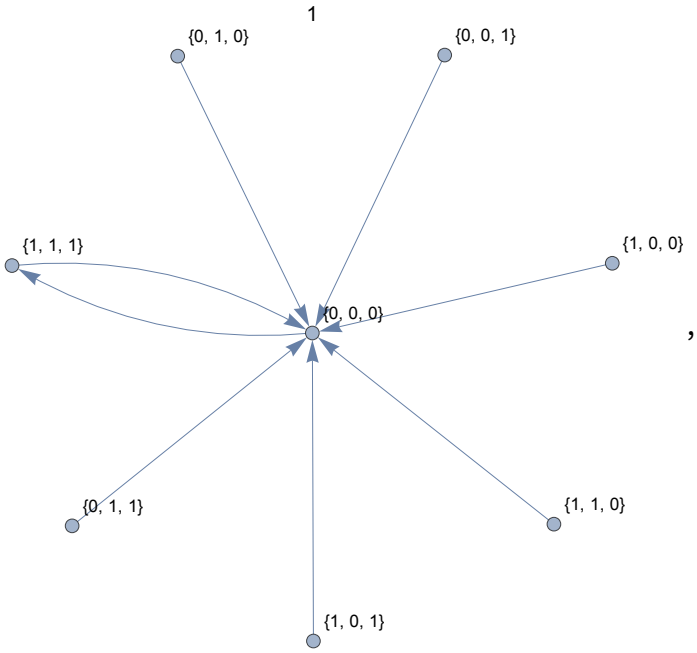
In[•]:=
```
f[x_, r_] := Graph[Rule @@@ x, VertexLabels → "Name", PlotLabel → r, ImageSize → Medium ]
```

Now let's apply our function in a loop to our results Table in a new Table loop!

In[•]:=
```
Table[f[results[[r + 1]], r], {r, 0, 255}]
```

Out[•]=

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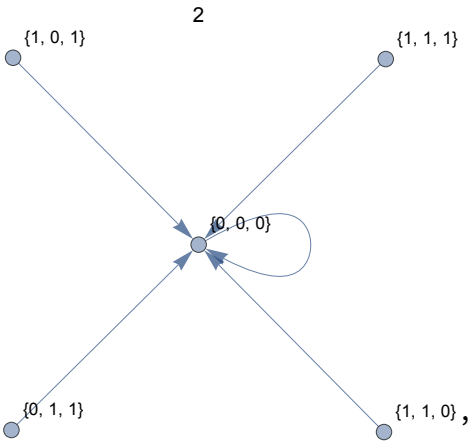
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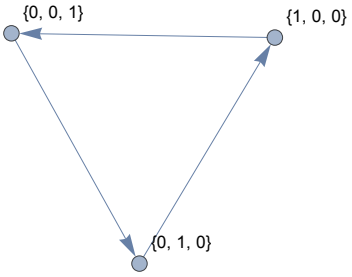
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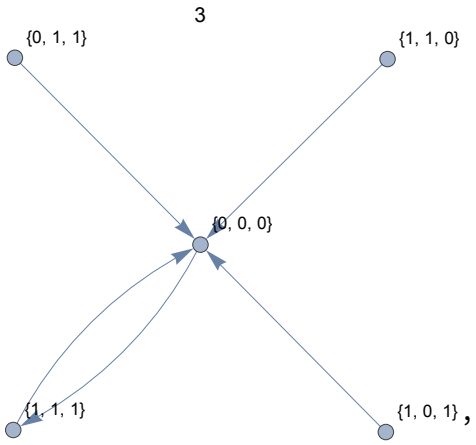
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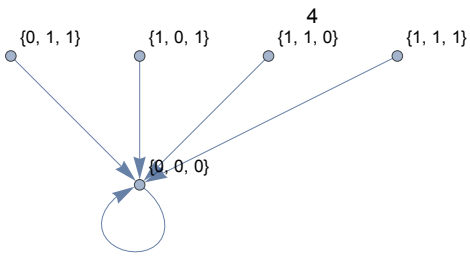
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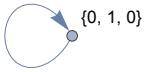
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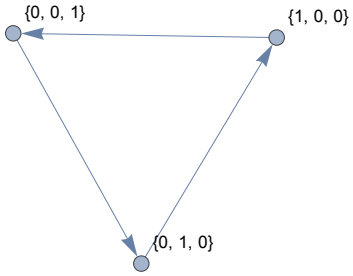
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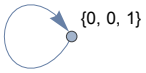
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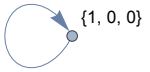
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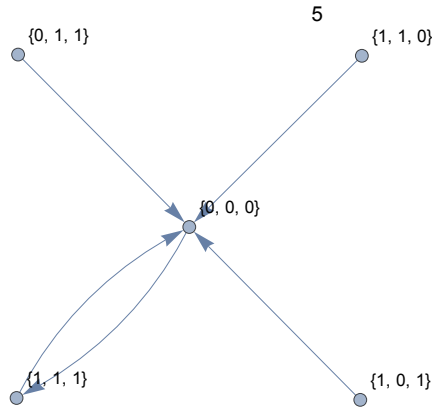
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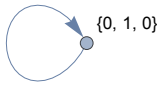
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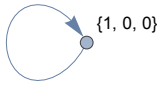
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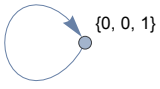
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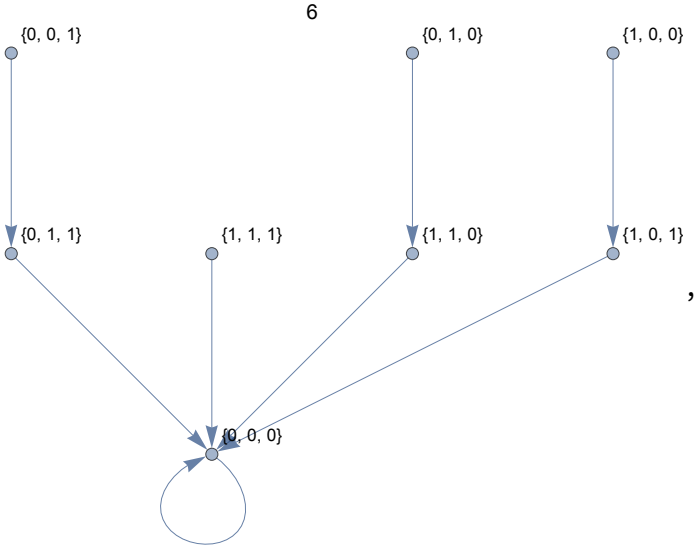

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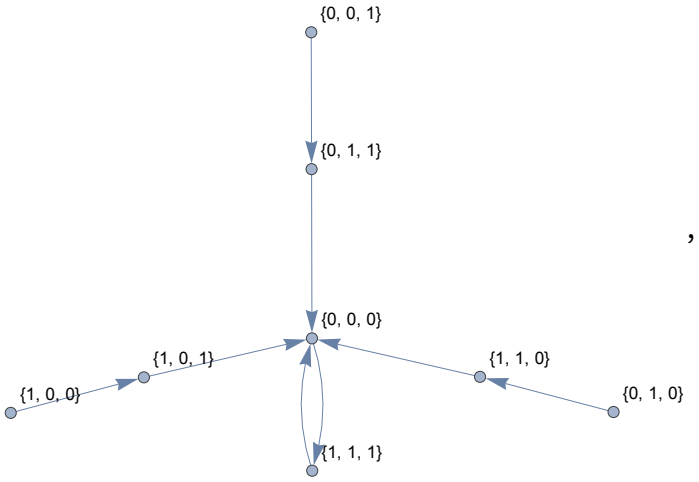

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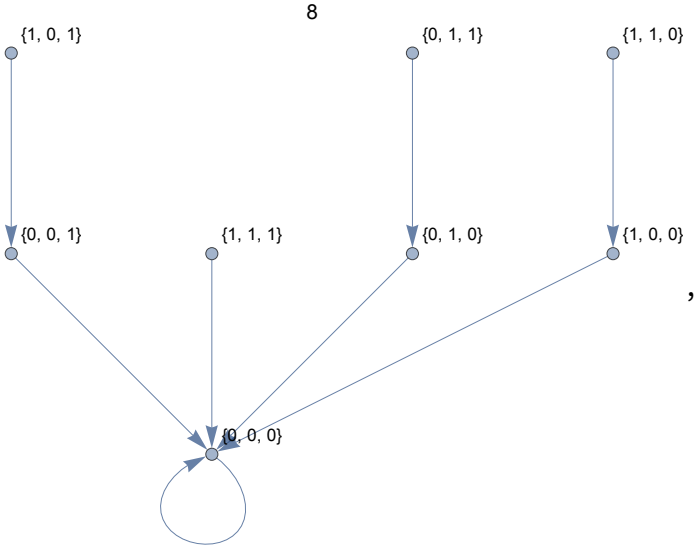

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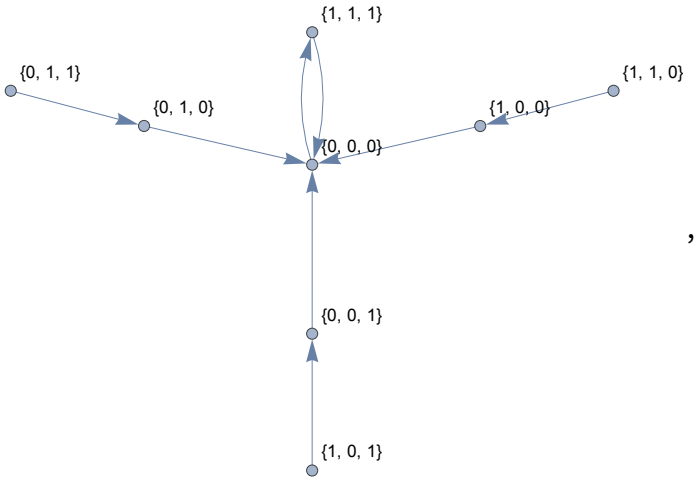

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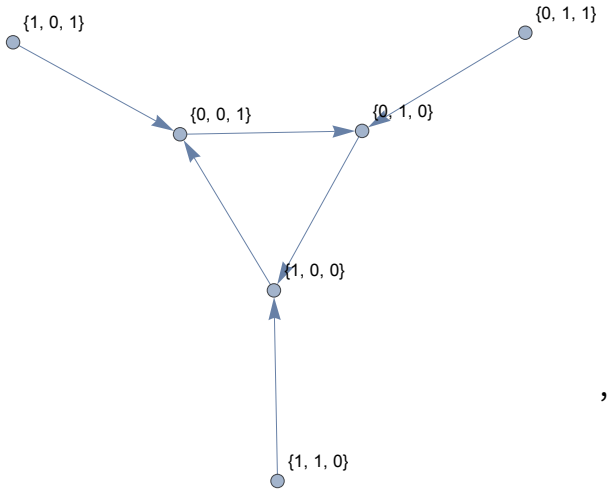

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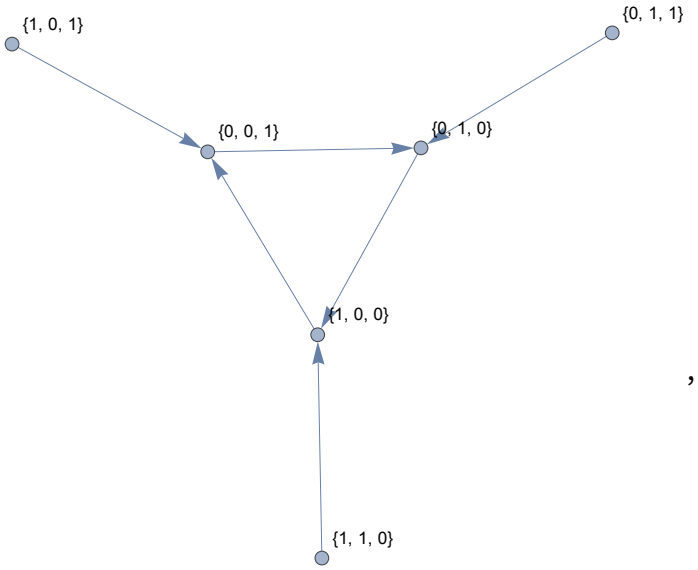

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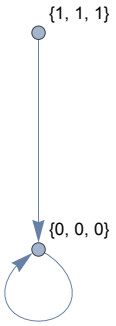

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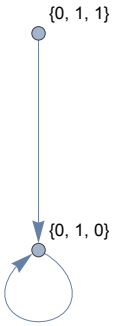

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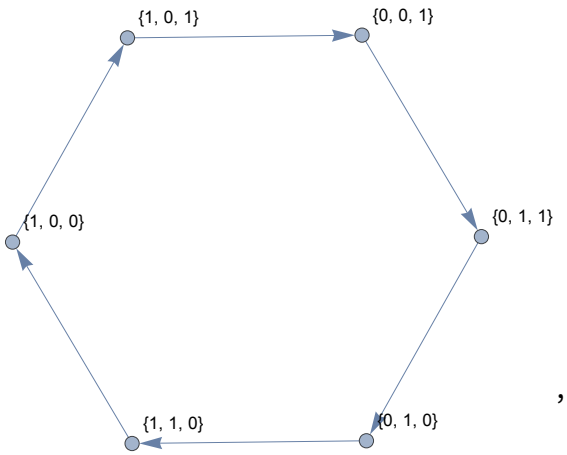

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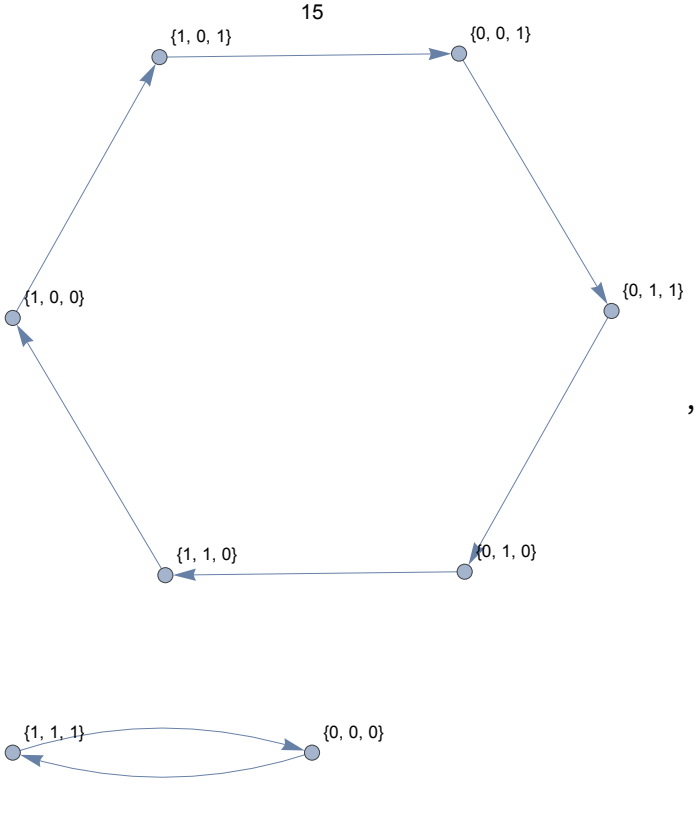

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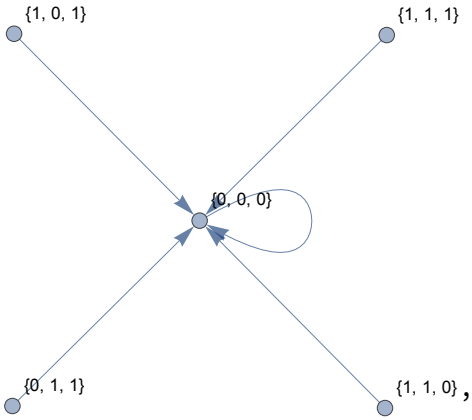

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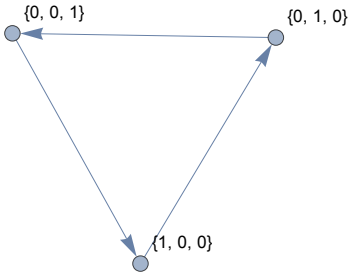

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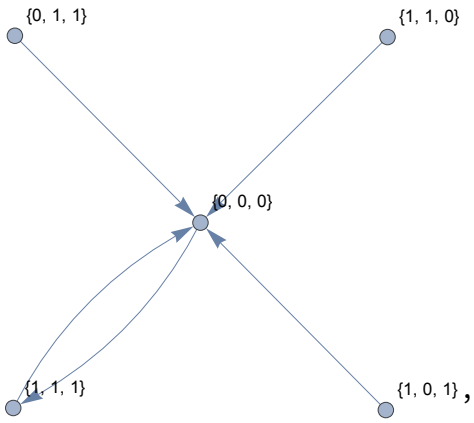
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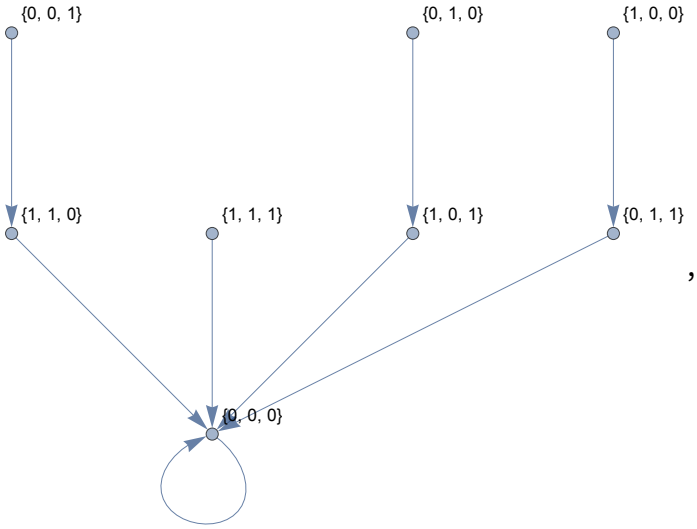
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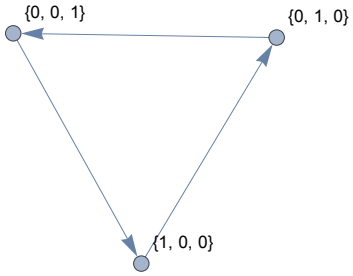
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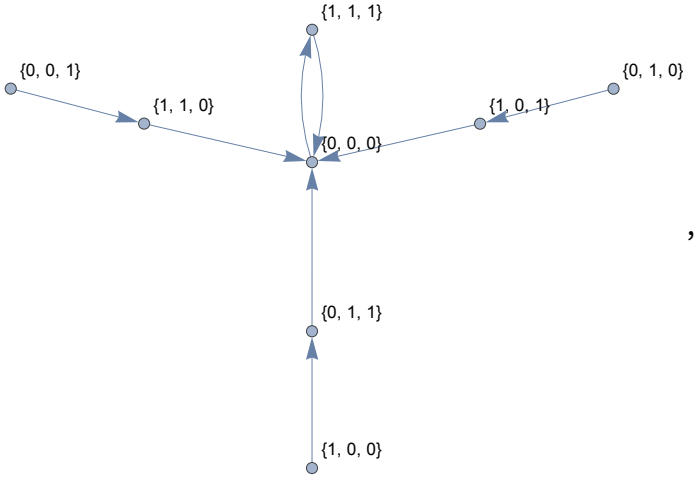
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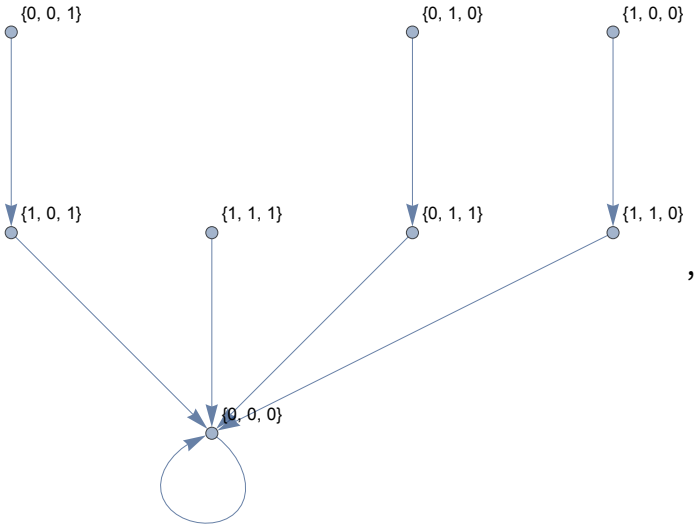

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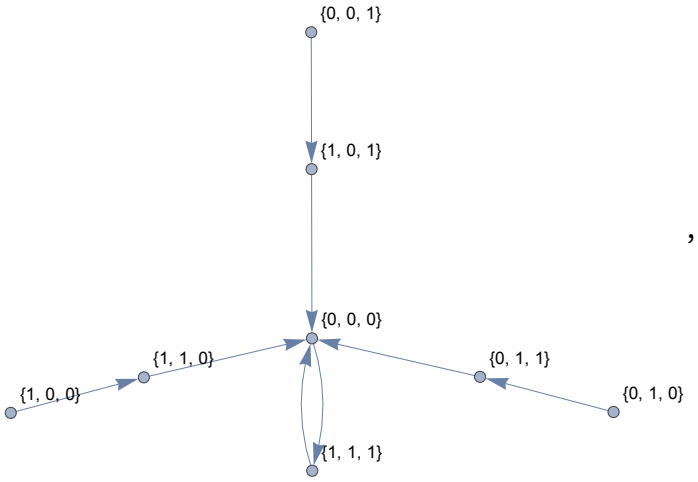

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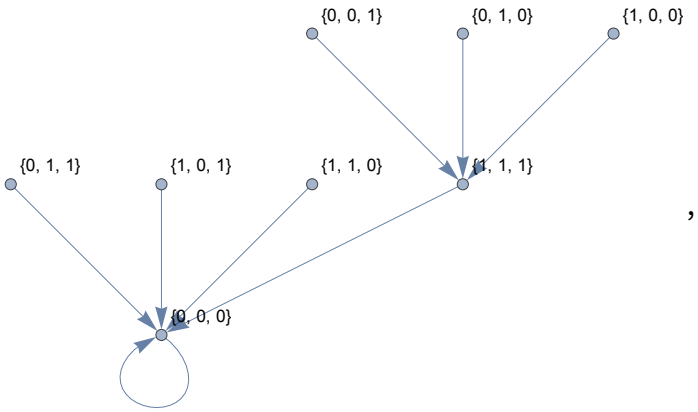

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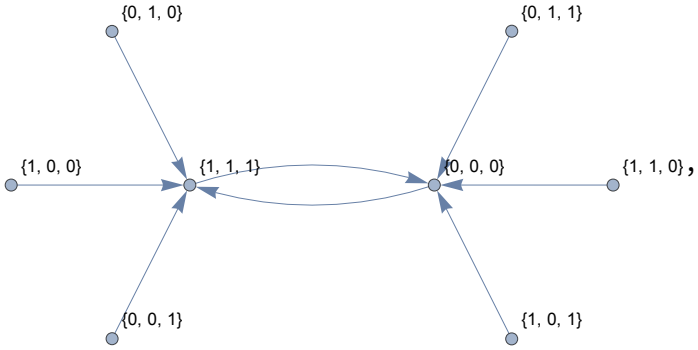

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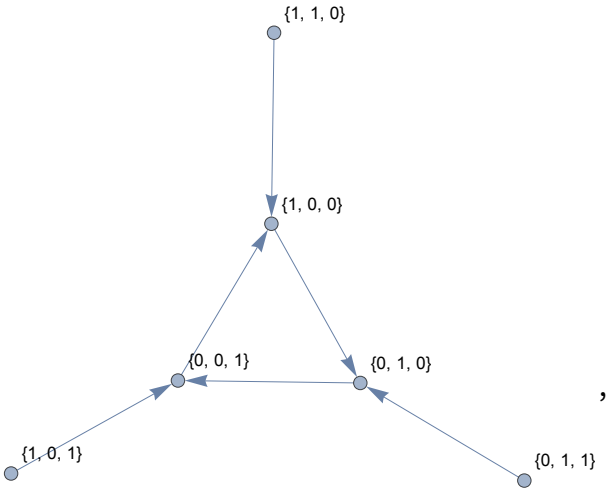

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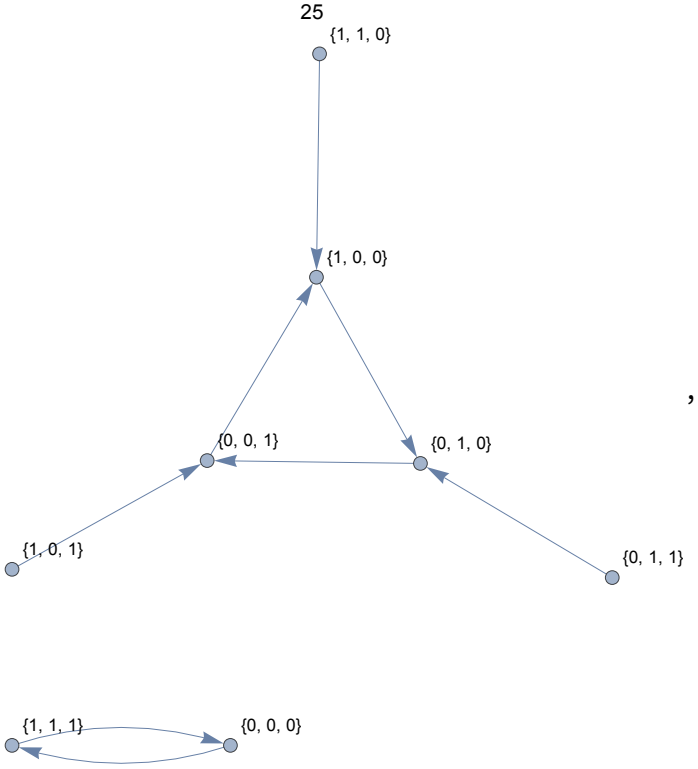

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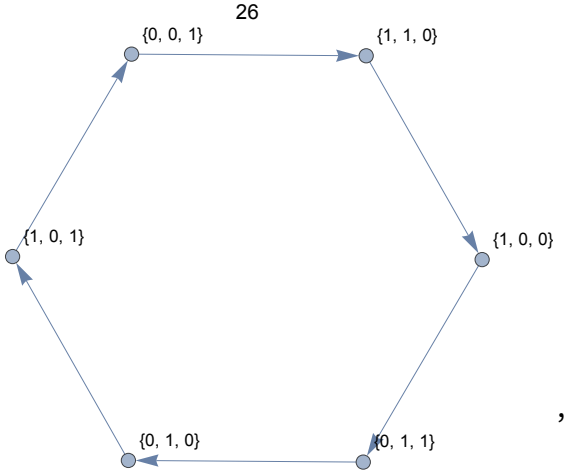

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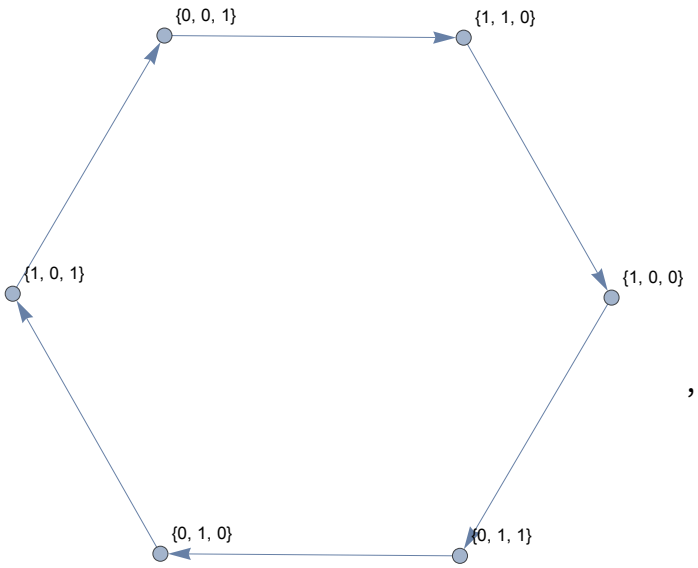

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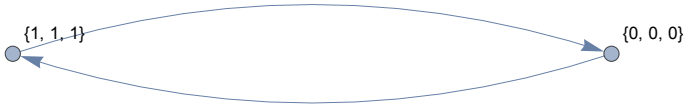

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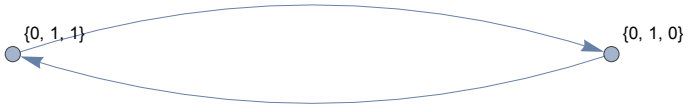

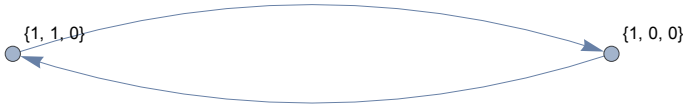

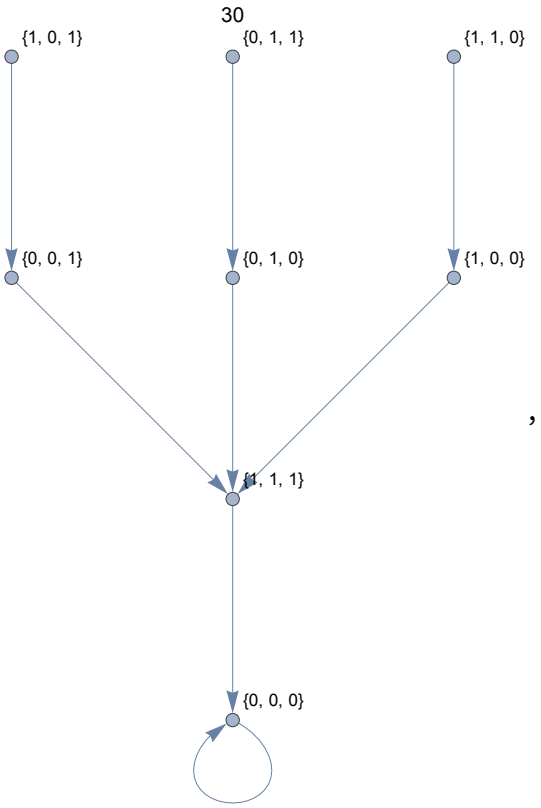
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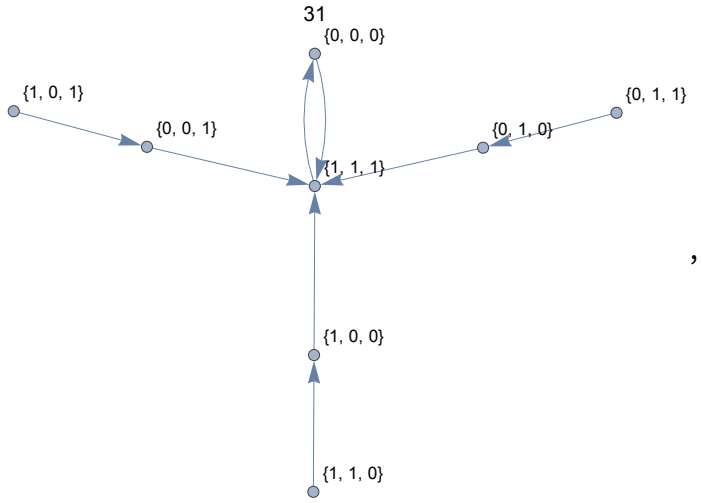
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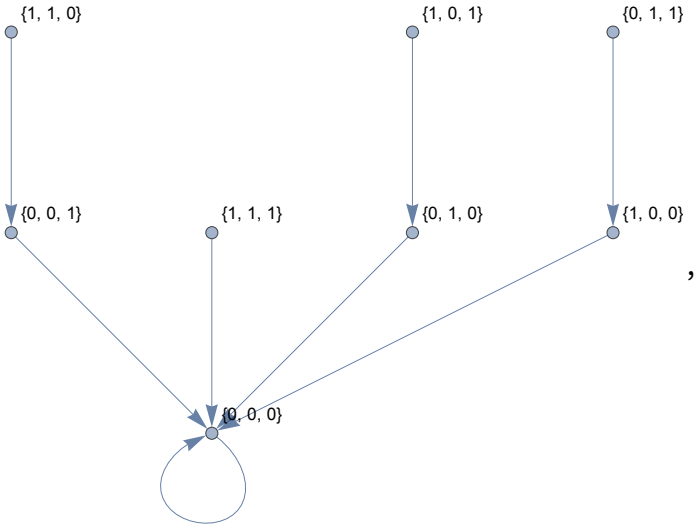

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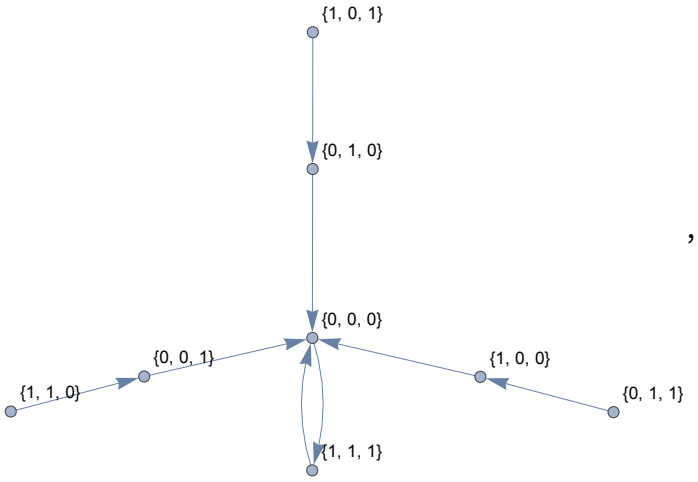

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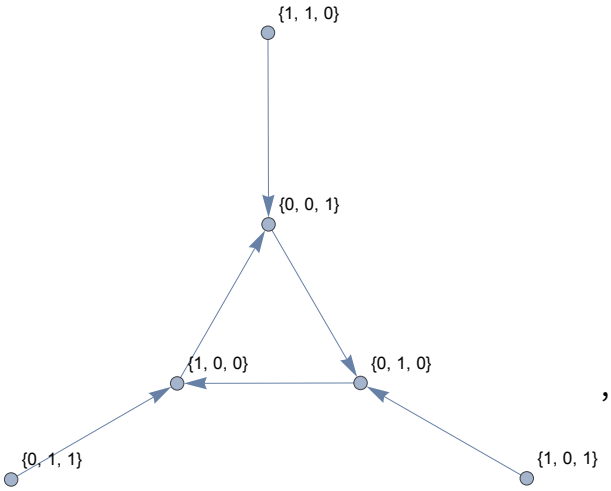

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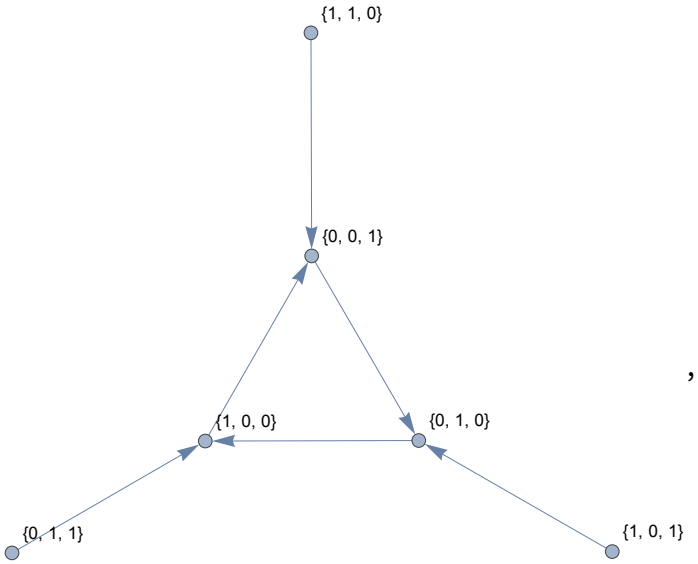

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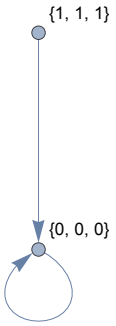

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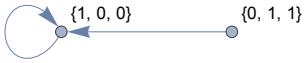

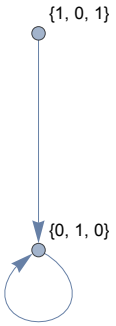

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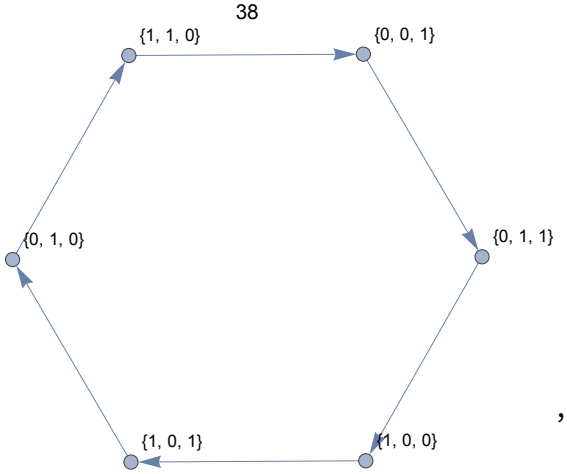

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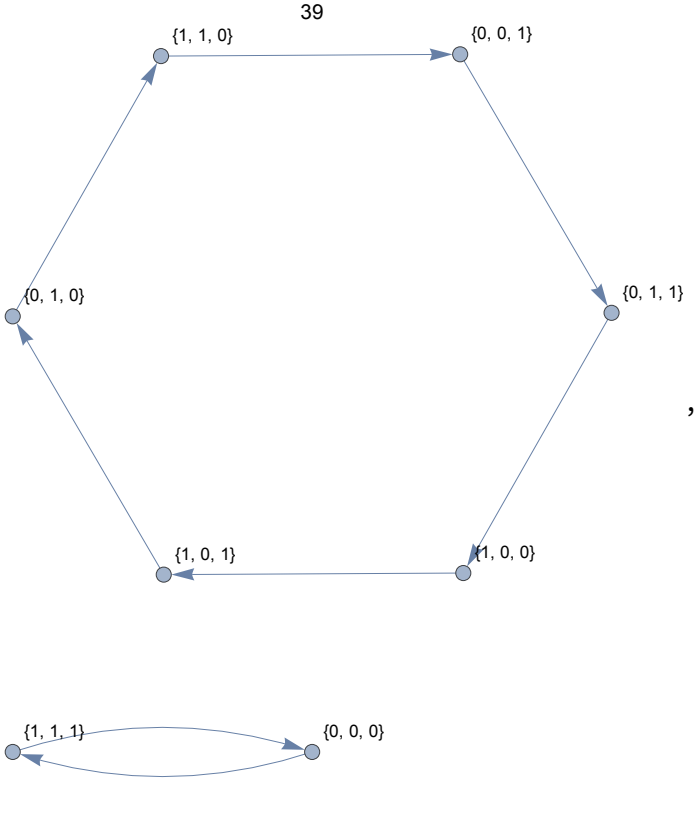

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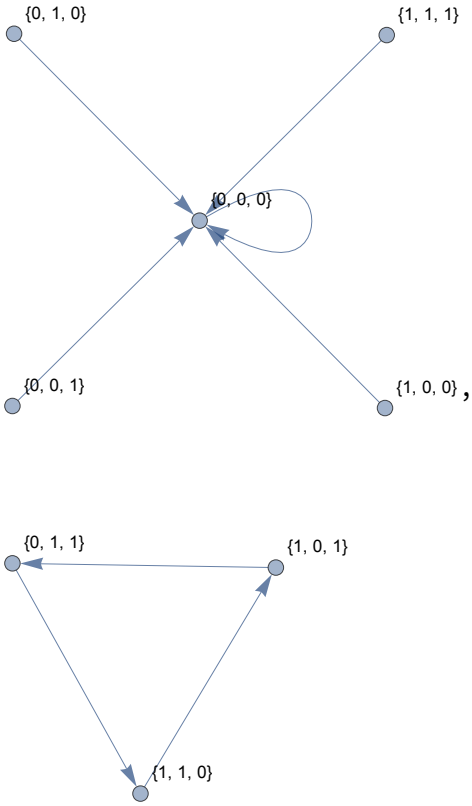

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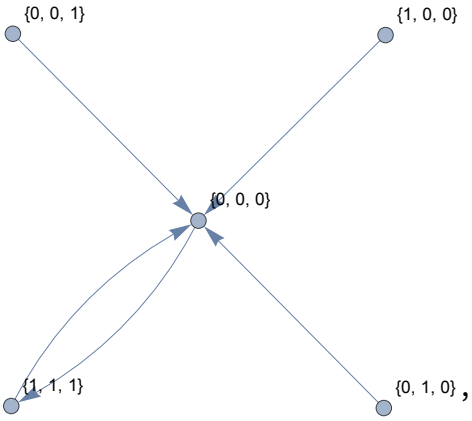
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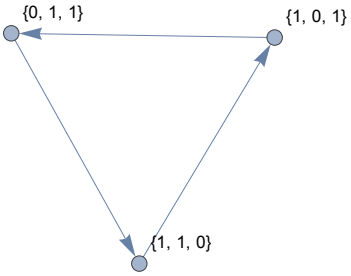
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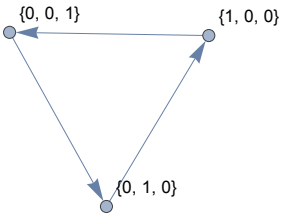
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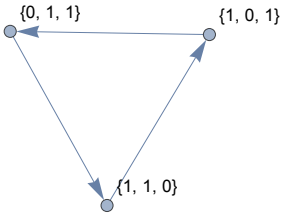
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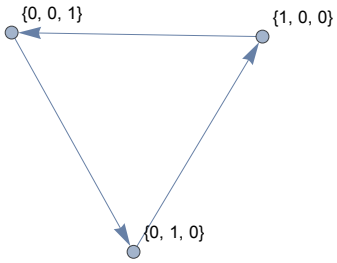
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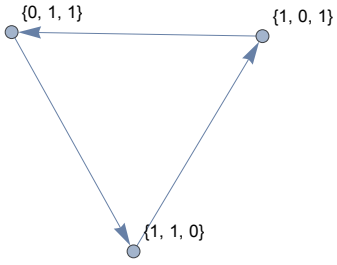
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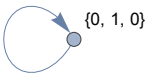

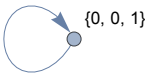

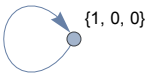

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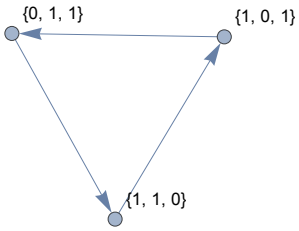

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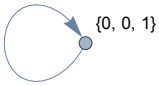

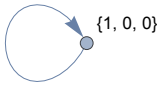

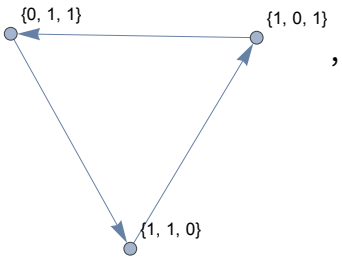

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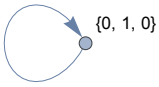

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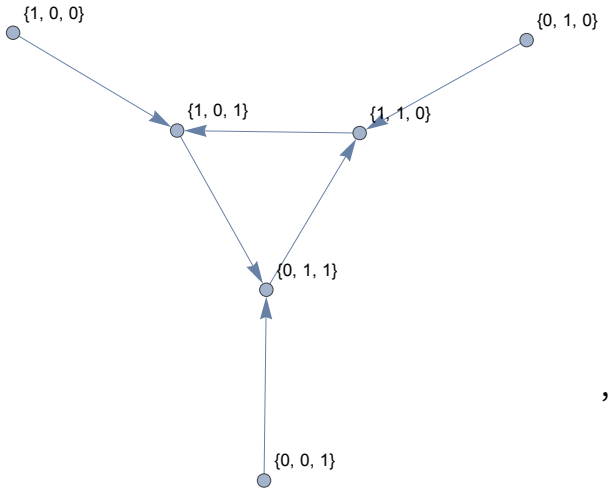

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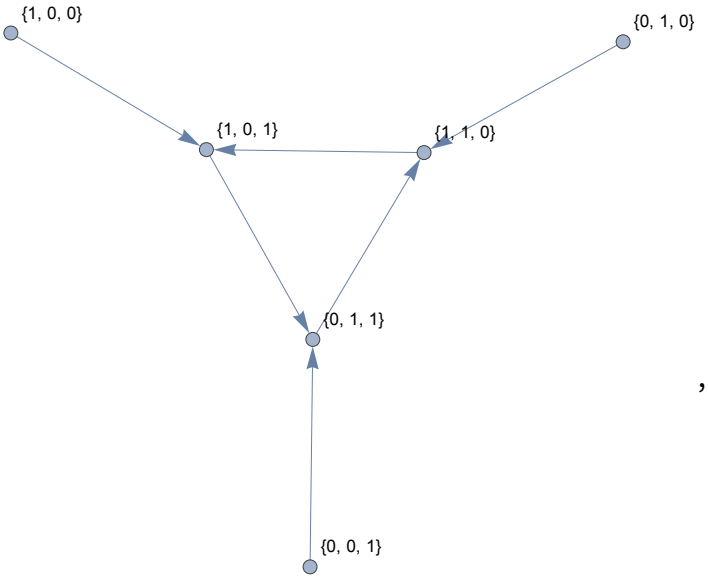

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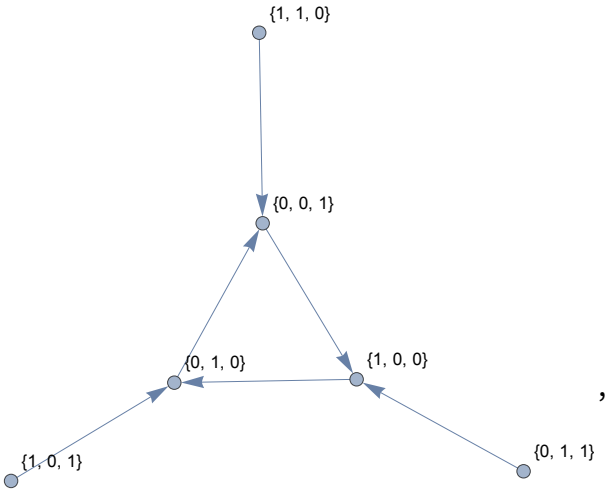

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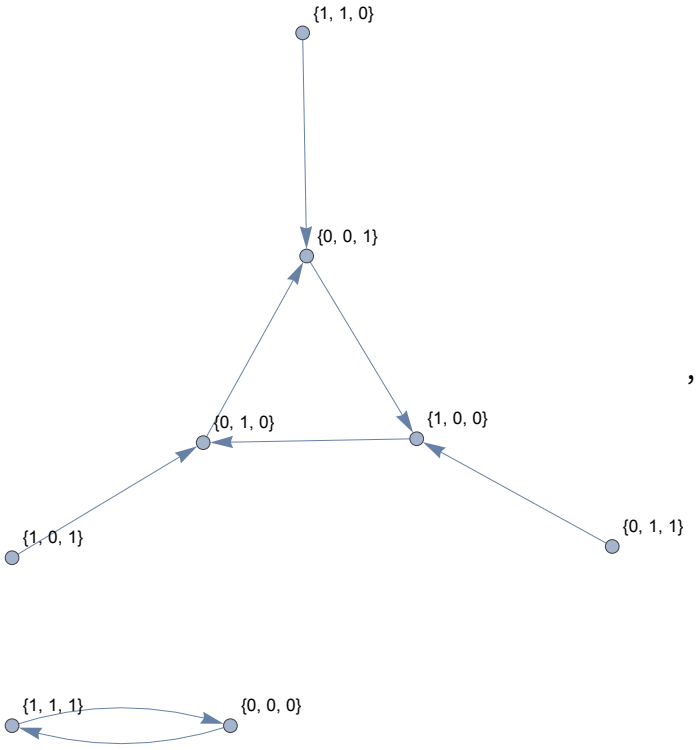

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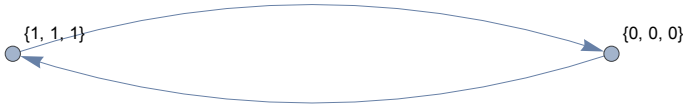

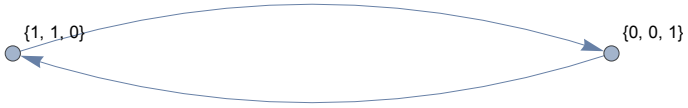

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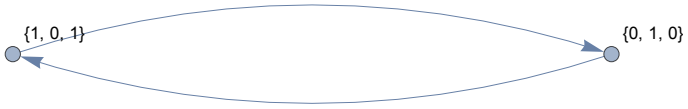

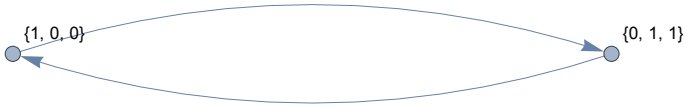

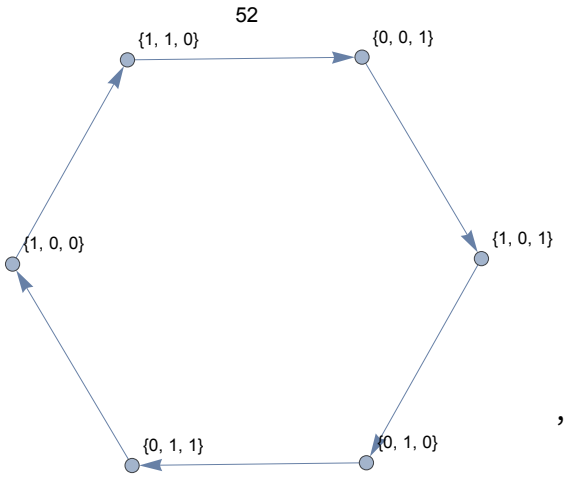
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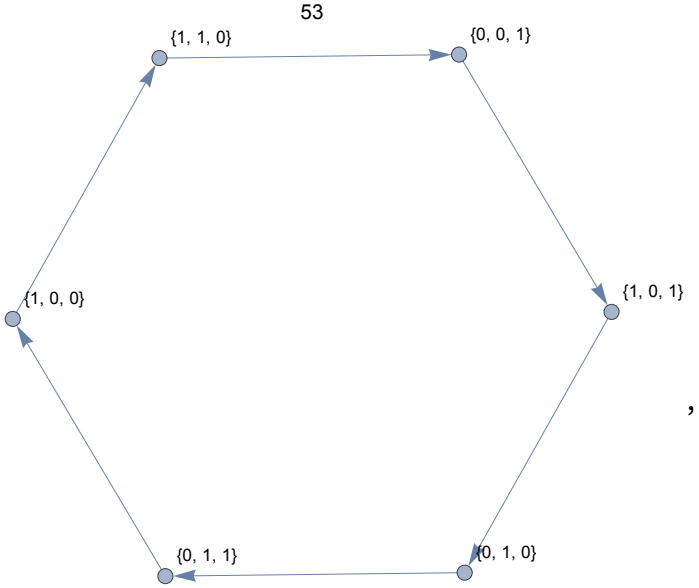

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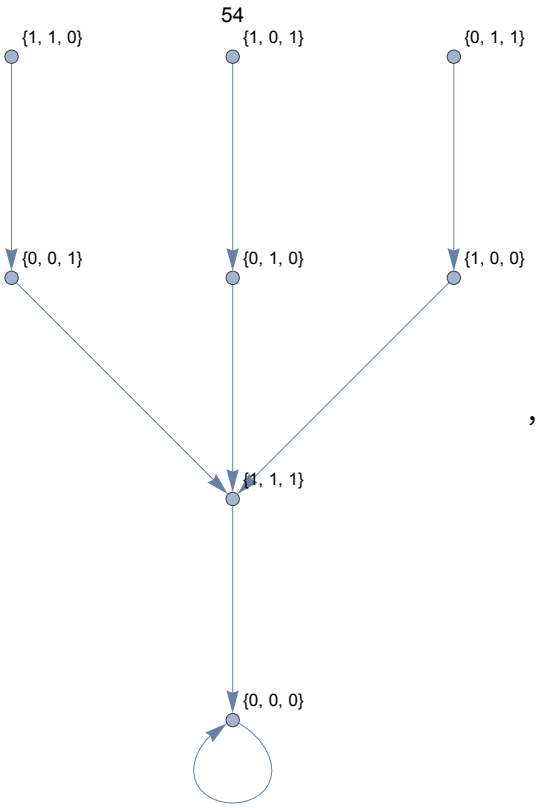
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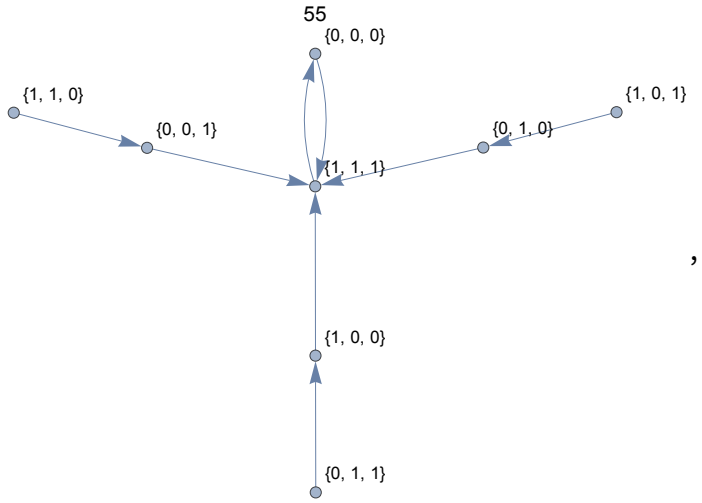
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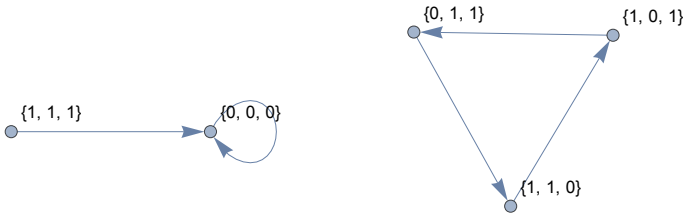

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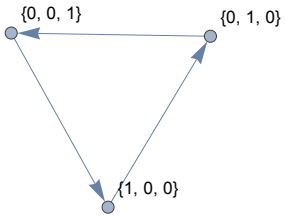

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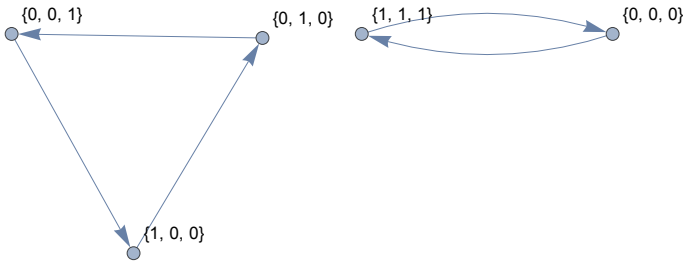

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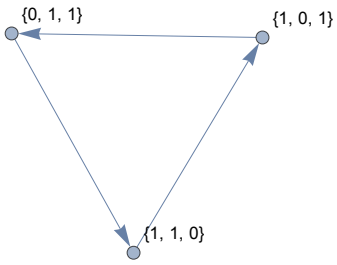

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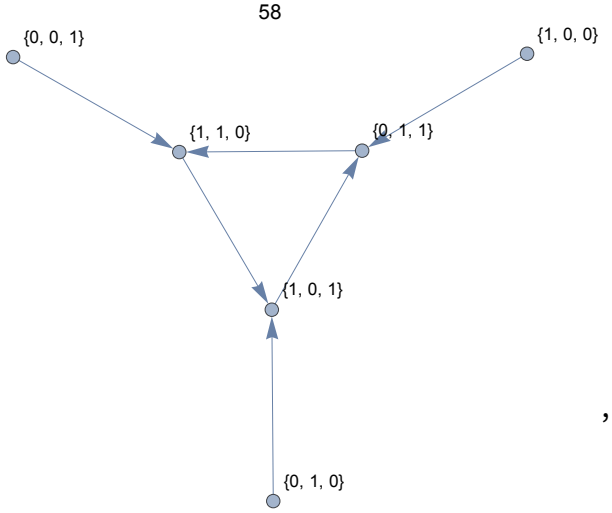

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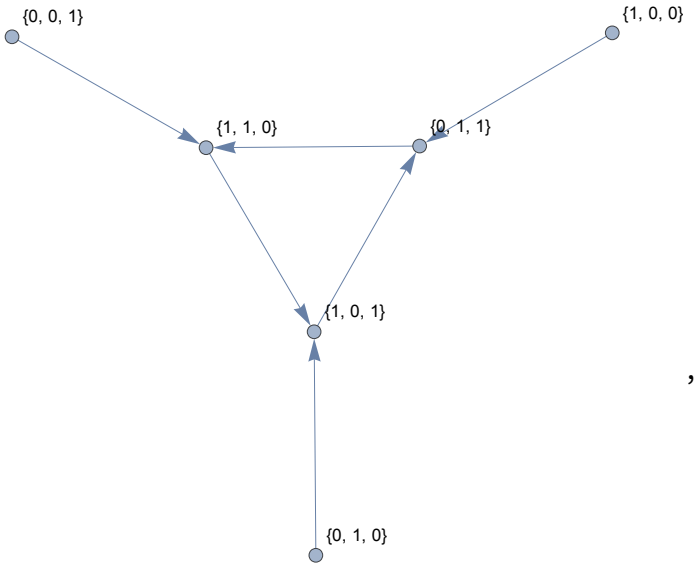

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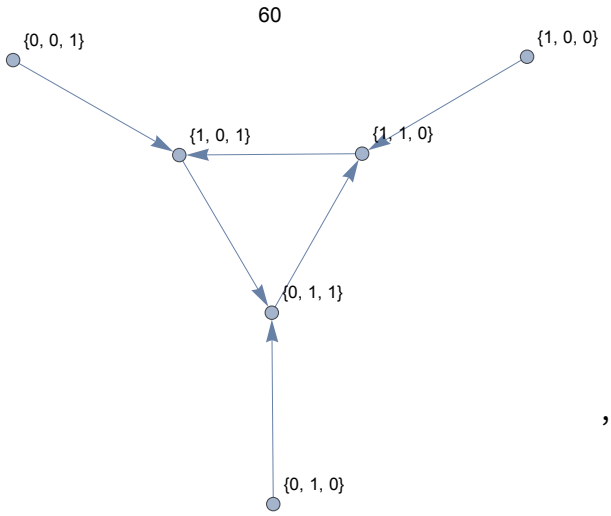
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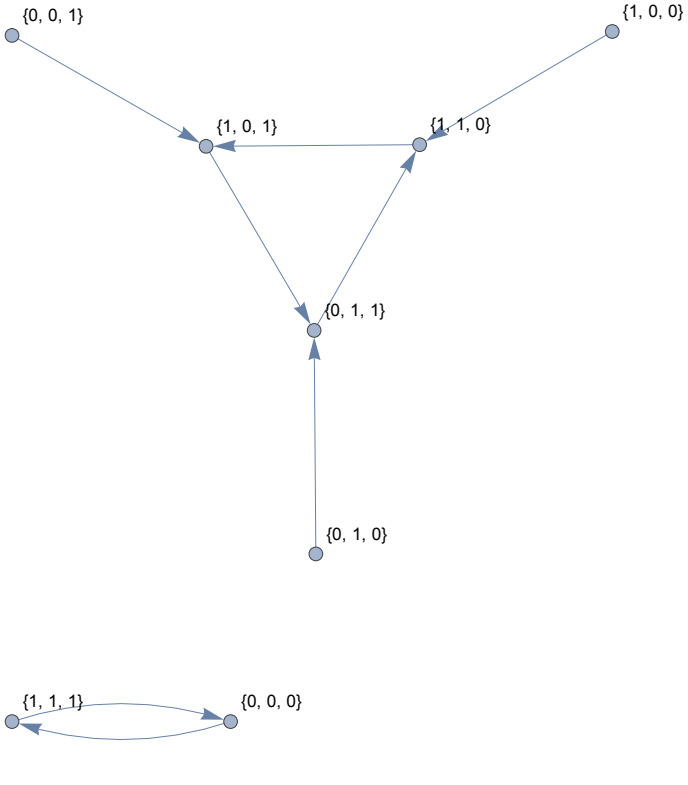

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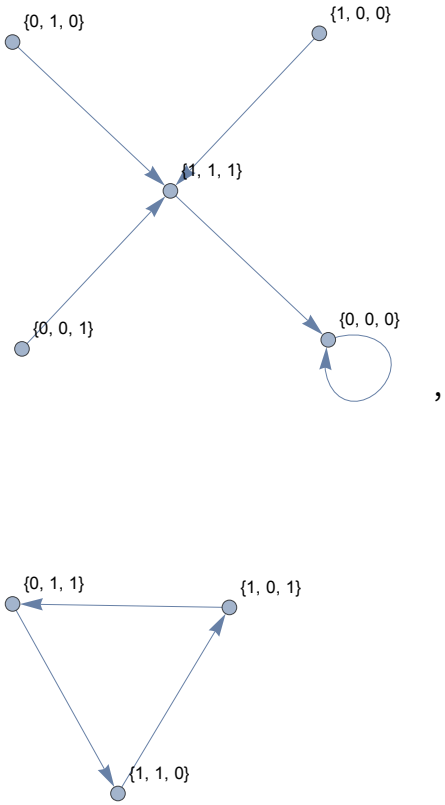

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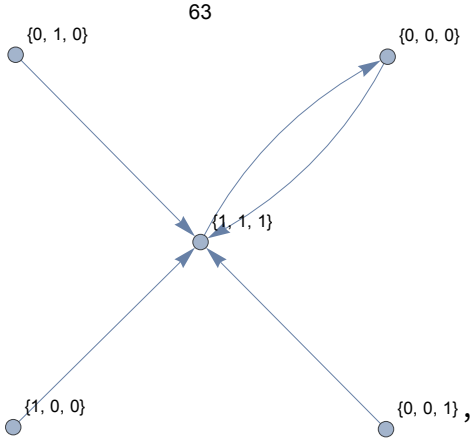
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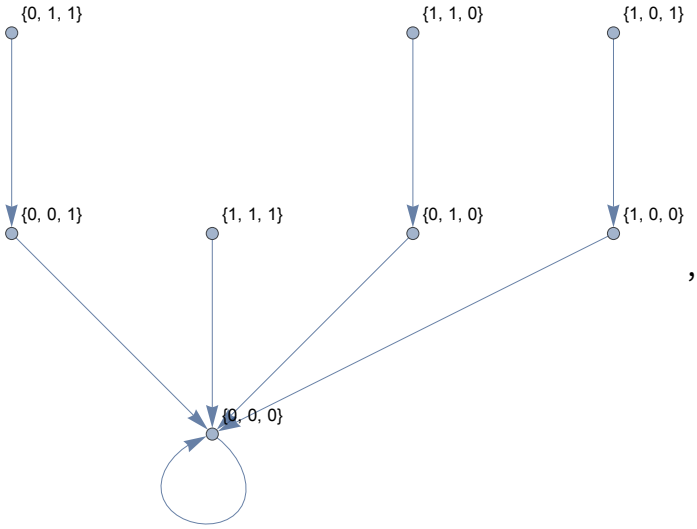
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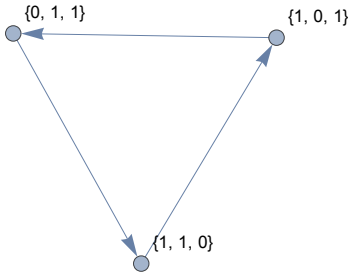
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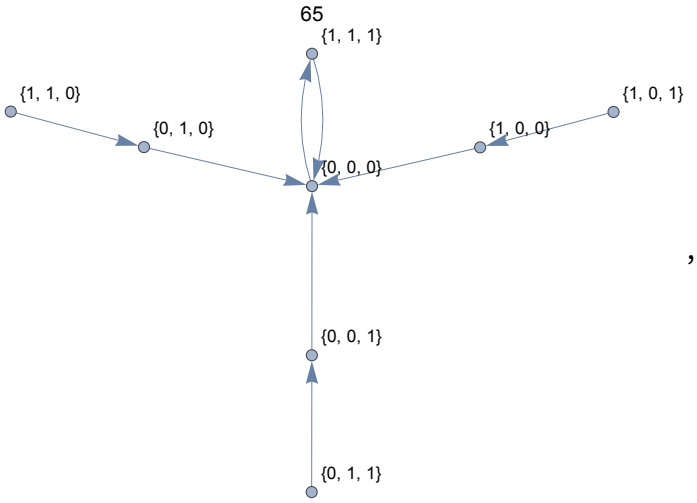
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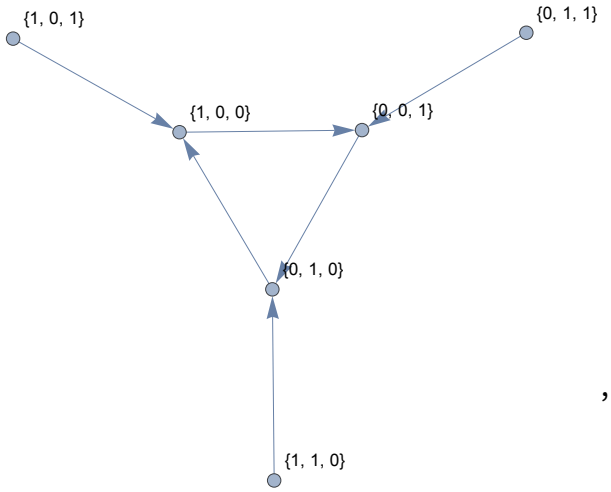

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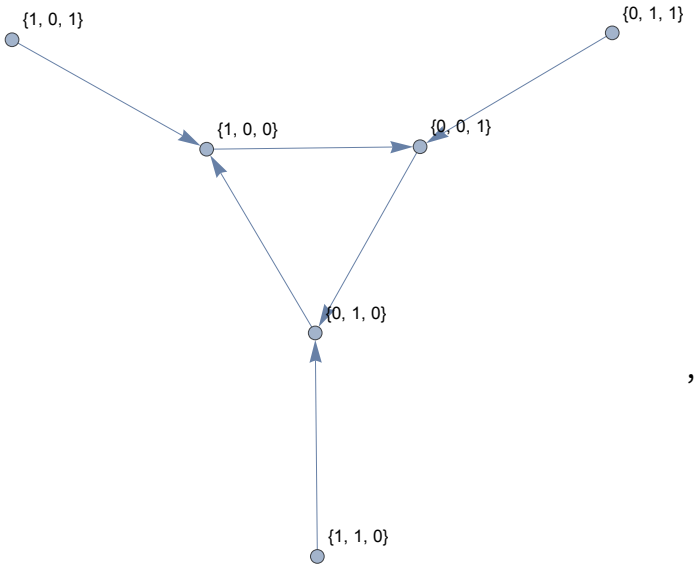

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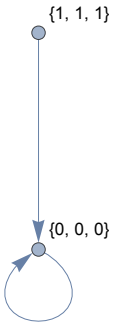

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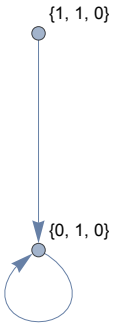

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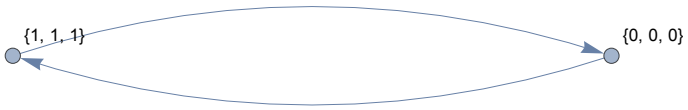

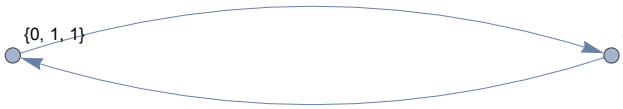

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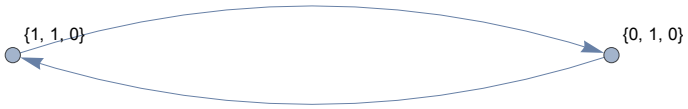

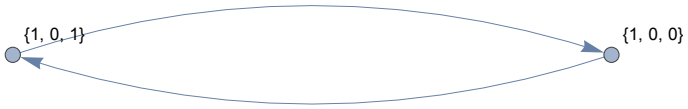

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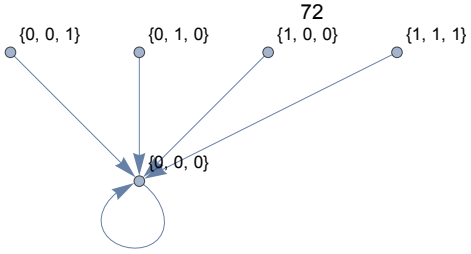

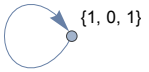

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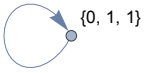

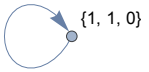

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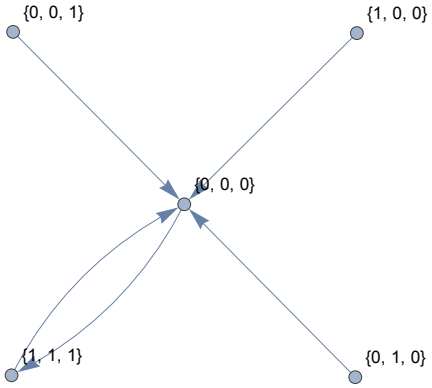

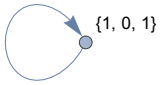

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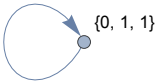

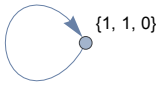

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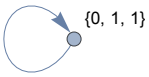

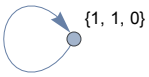

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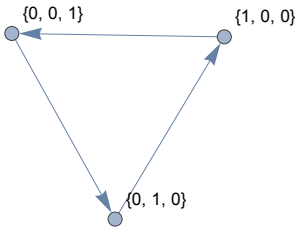

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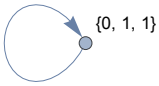

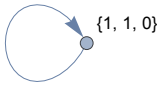

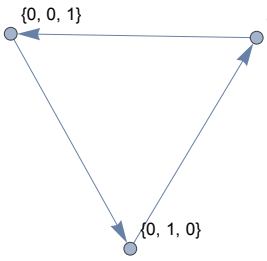

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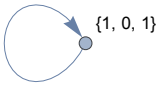

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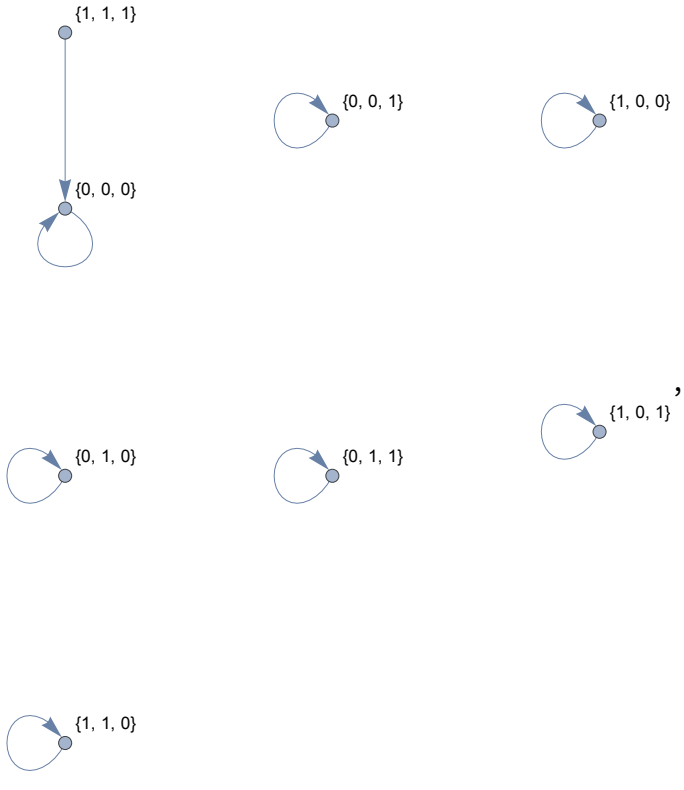

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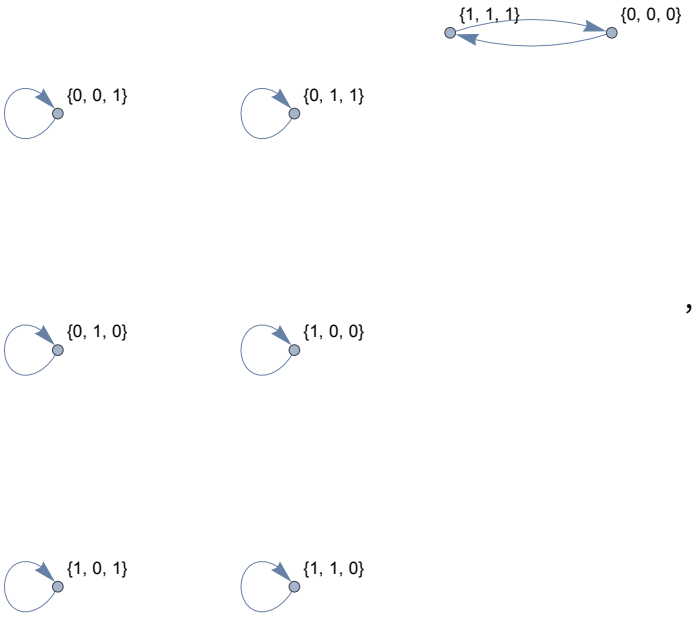

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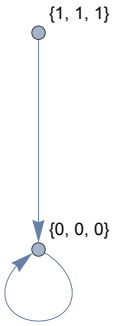

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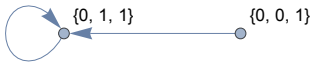

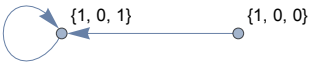

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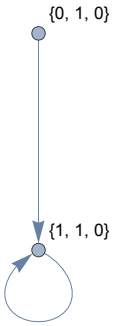

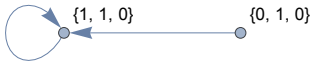

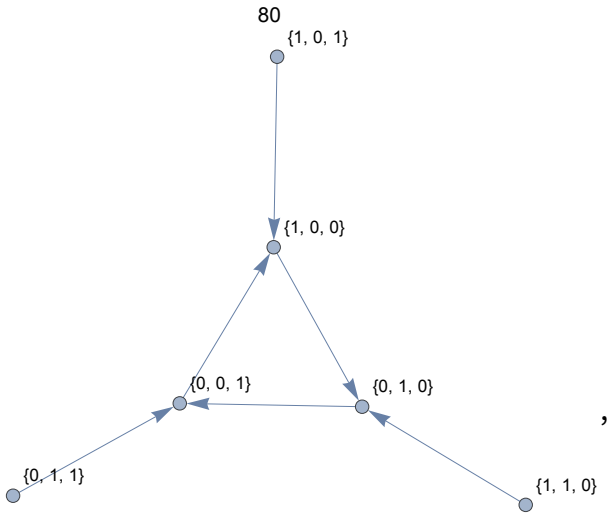
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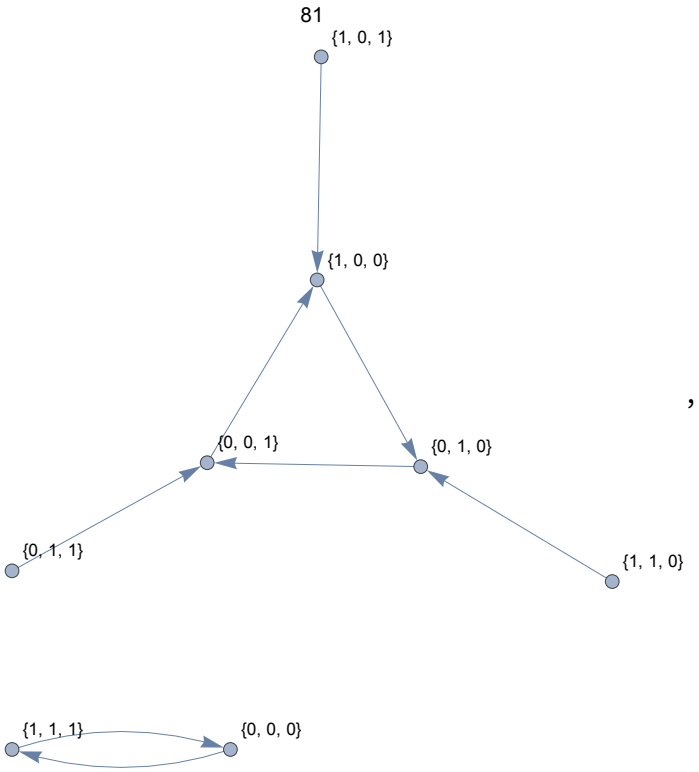
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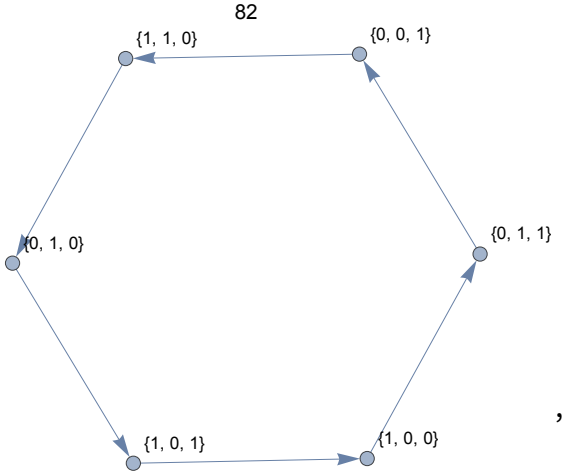

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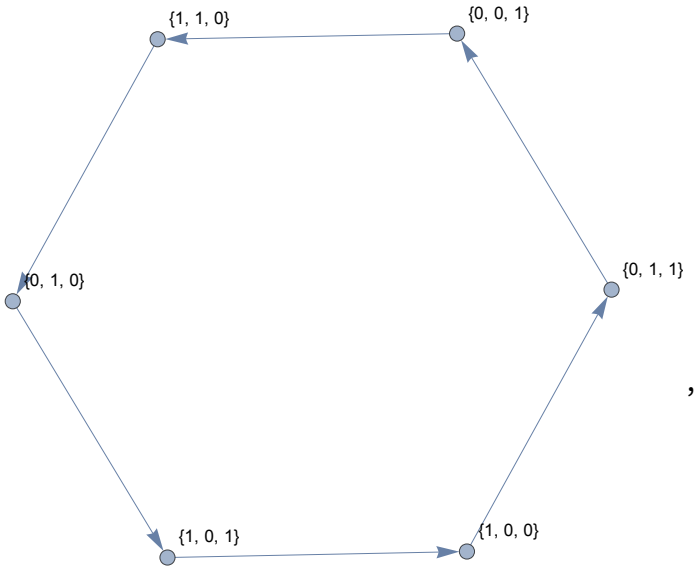

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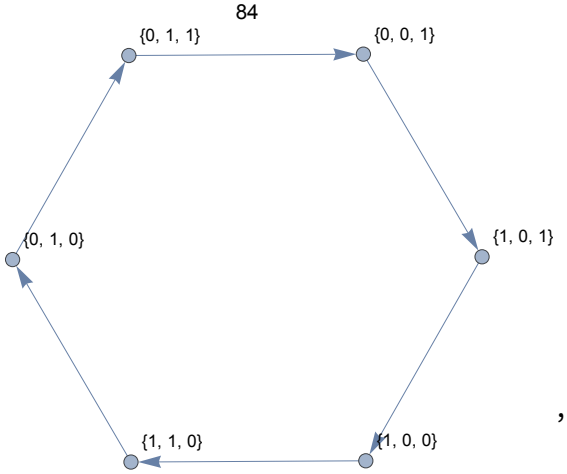

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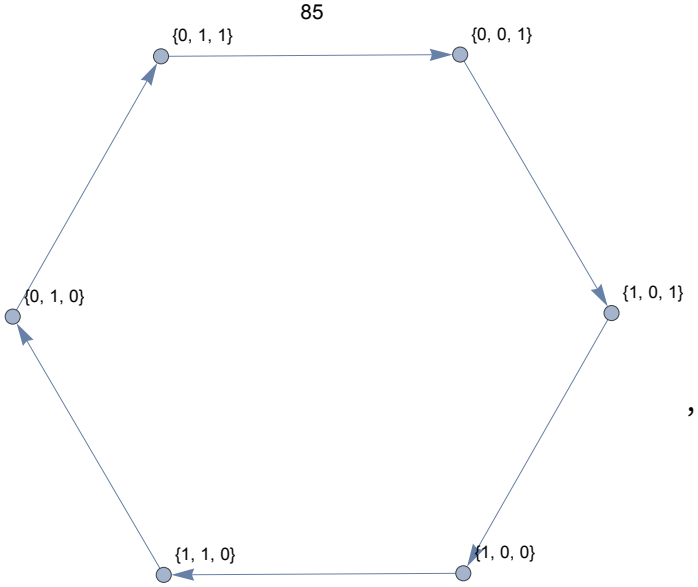

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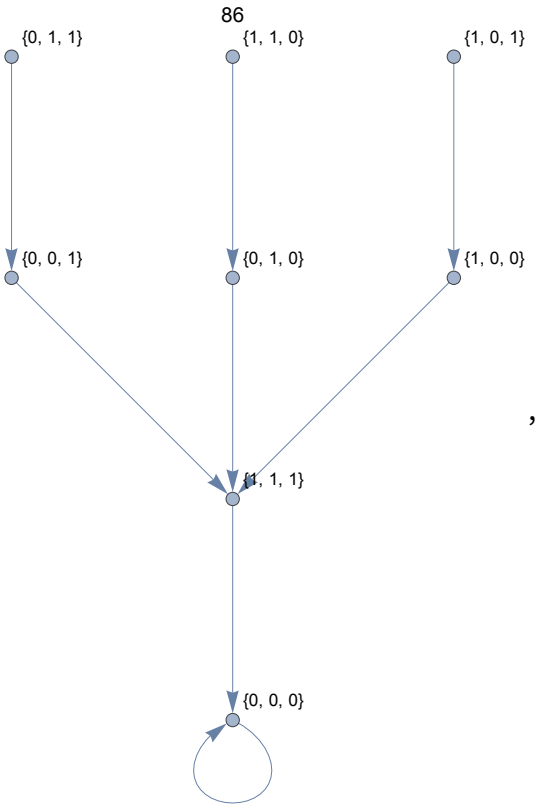
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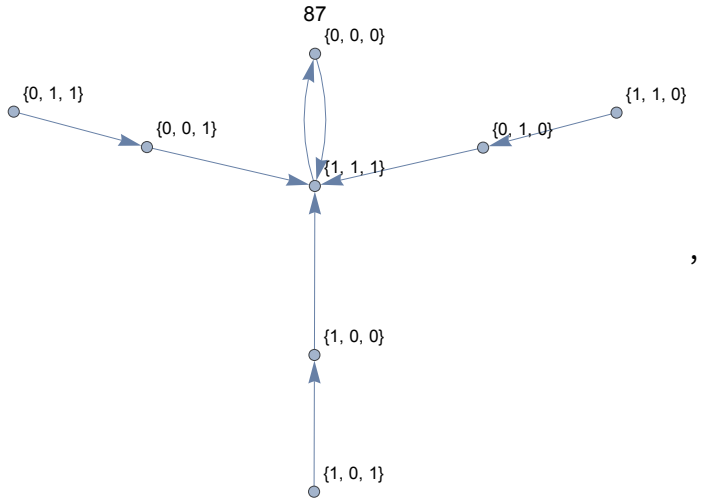
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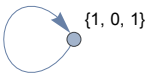

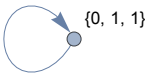

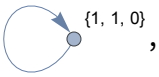

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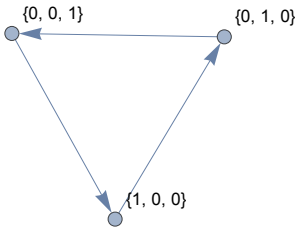

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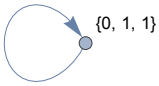

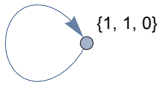

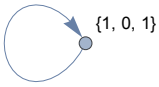

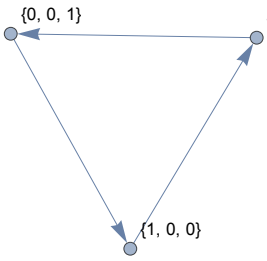

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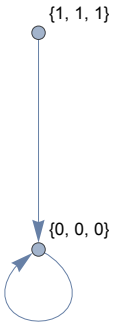

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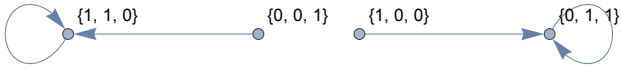

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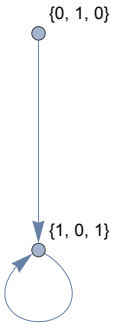

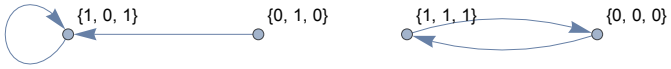

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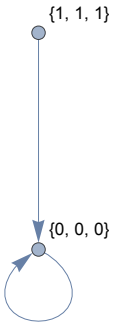

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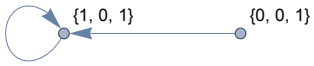

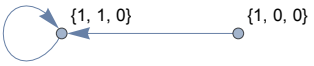

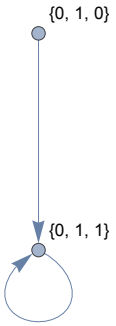

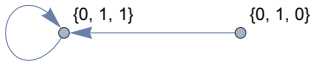

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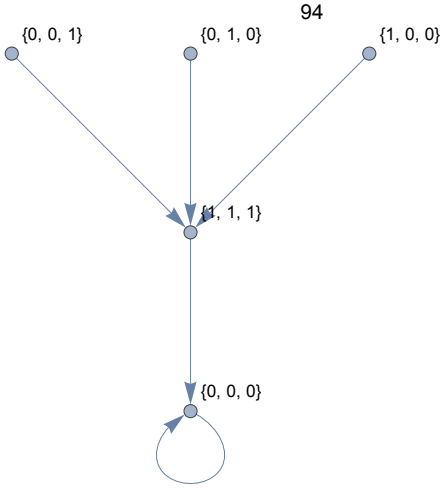

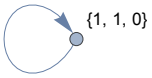

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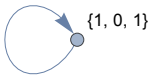

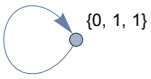

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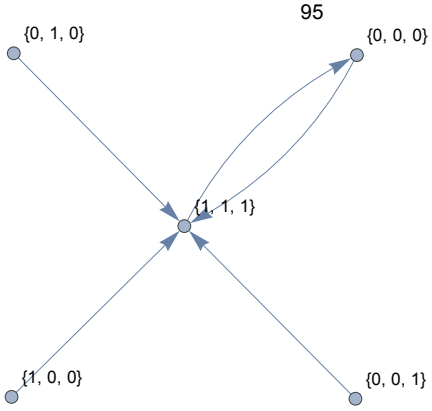

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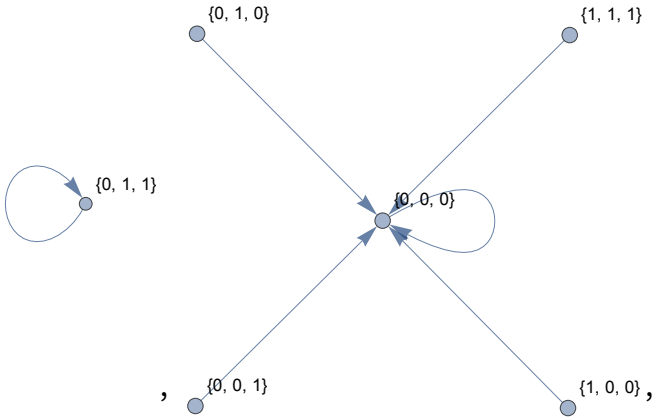

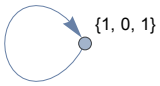

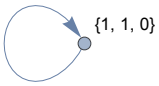

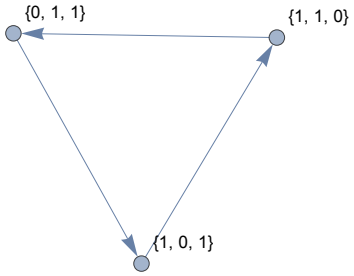

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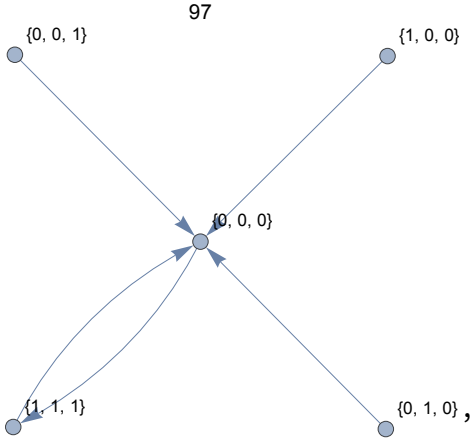
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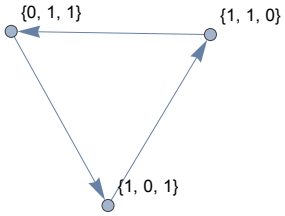
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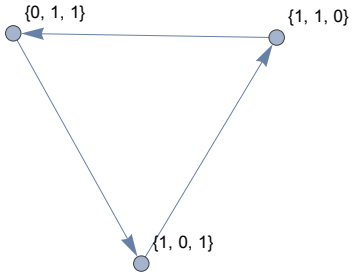
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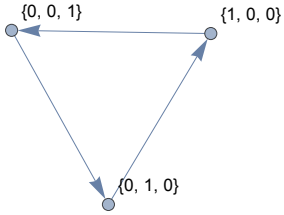
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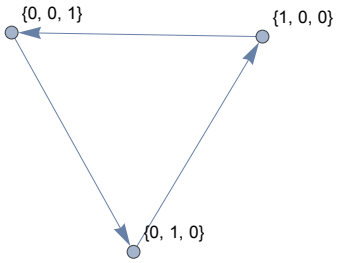
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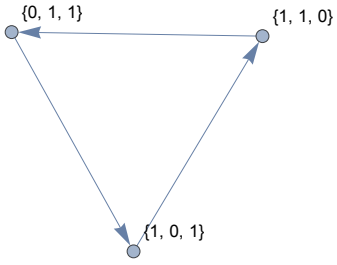
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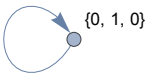

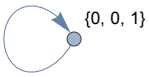

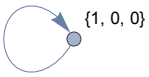

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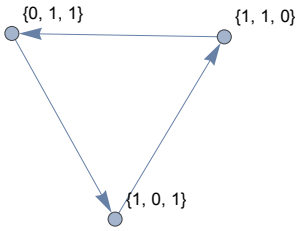

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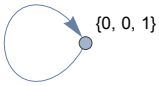

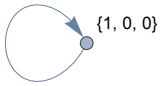

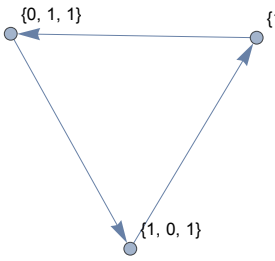

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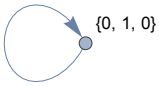

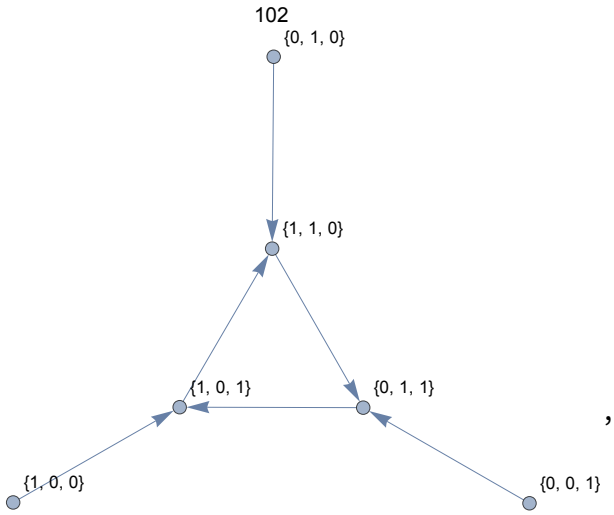
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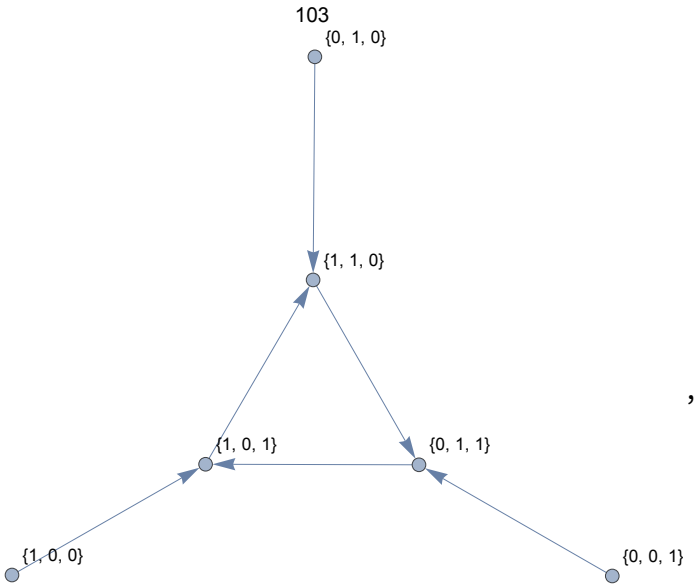
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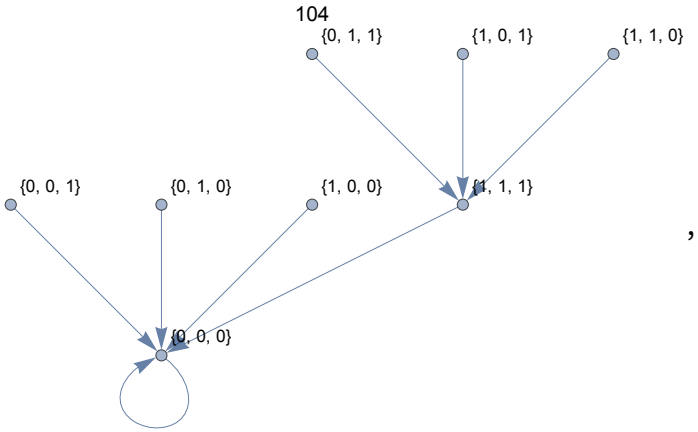
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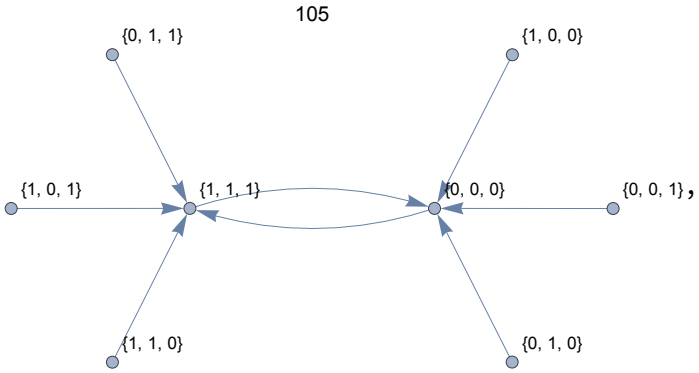
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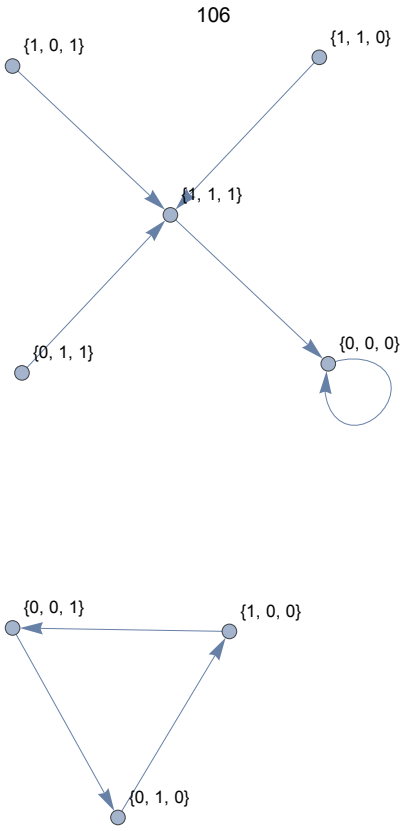
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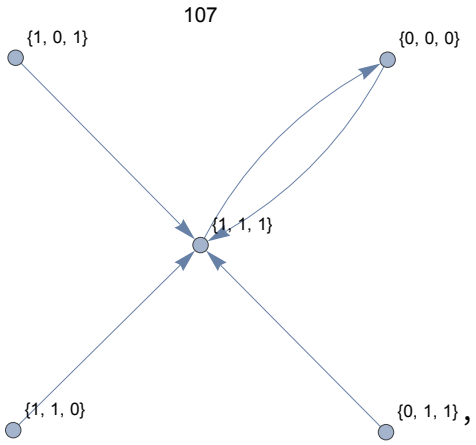
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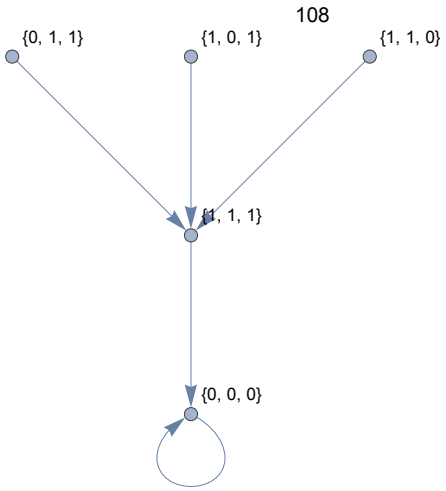
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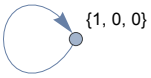
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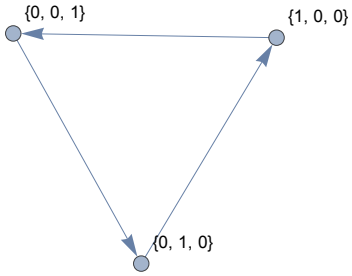
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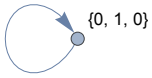
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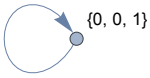
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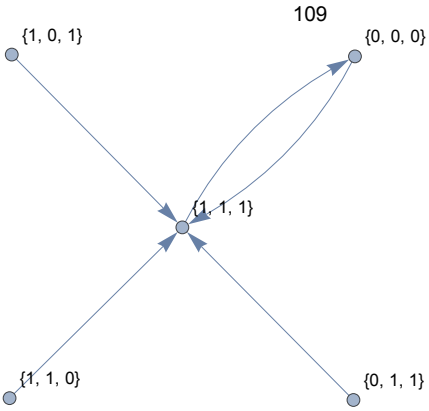
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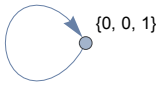
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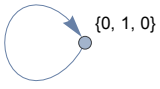
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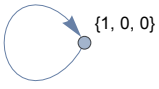
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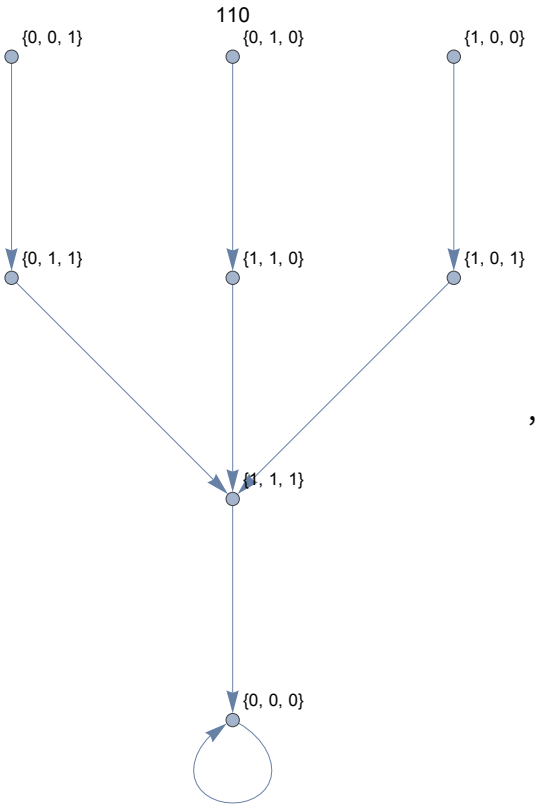
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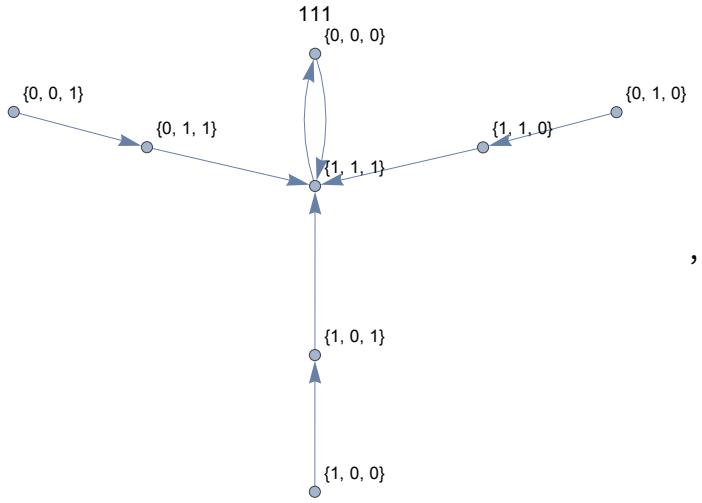
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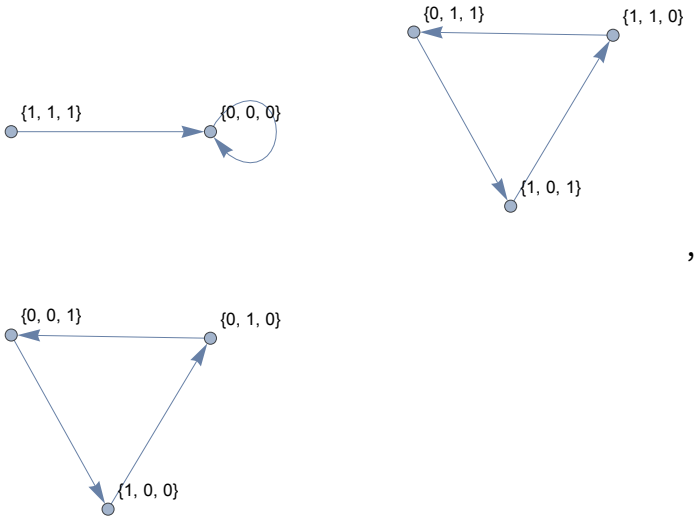

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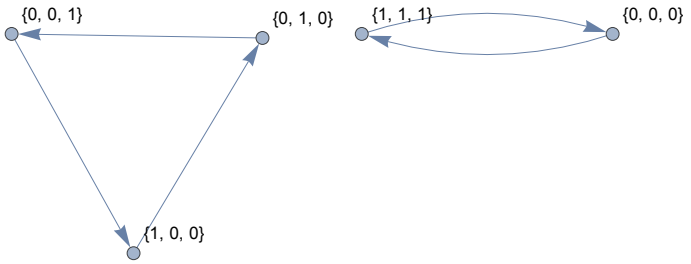

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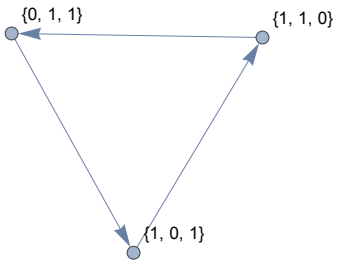

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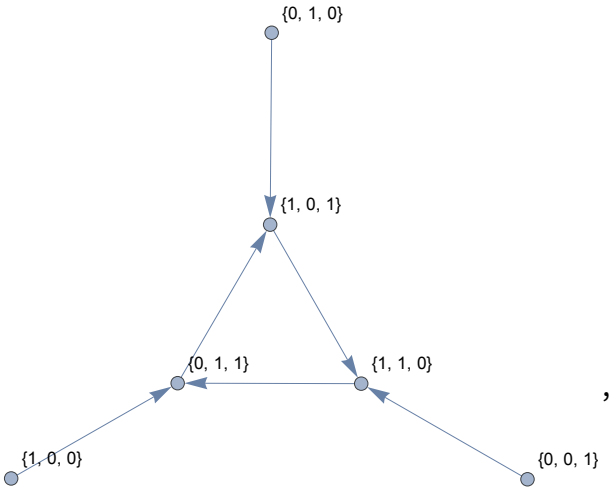

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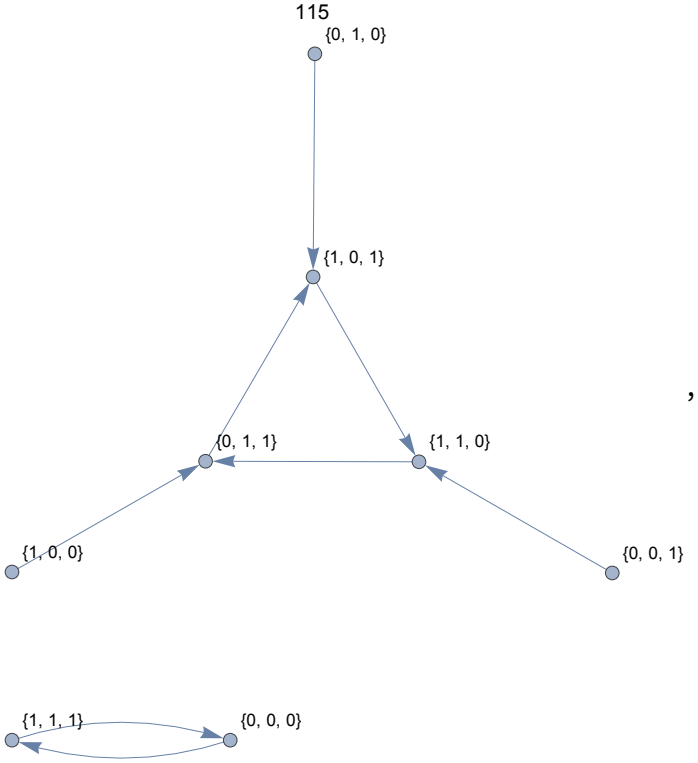

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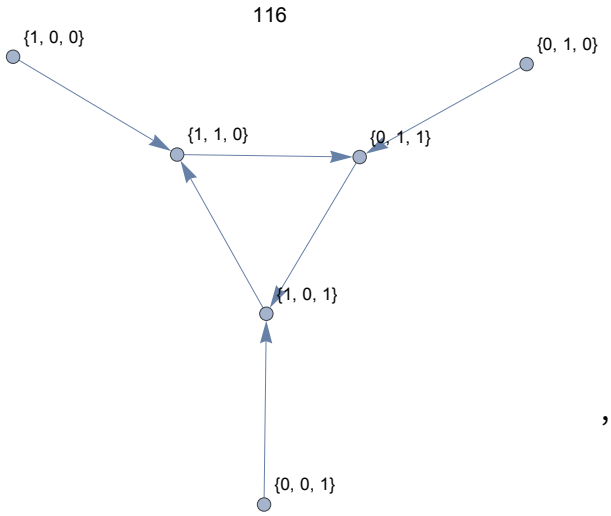
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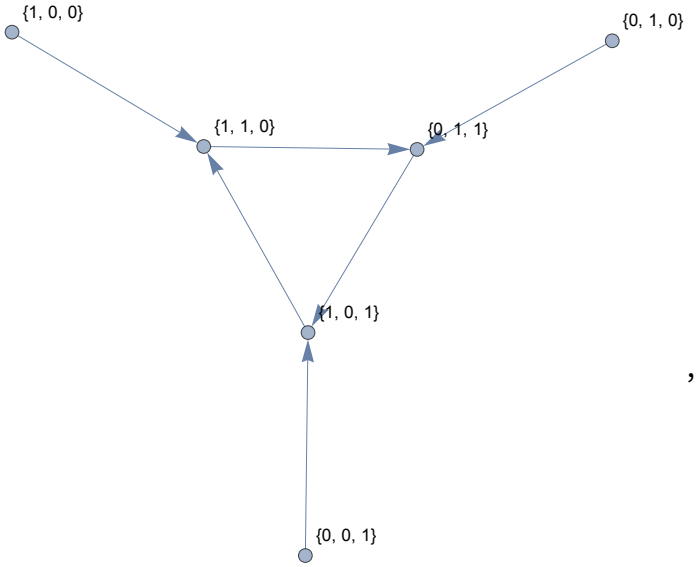

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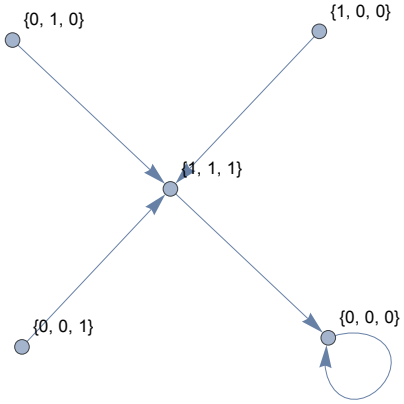

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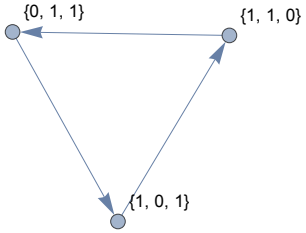

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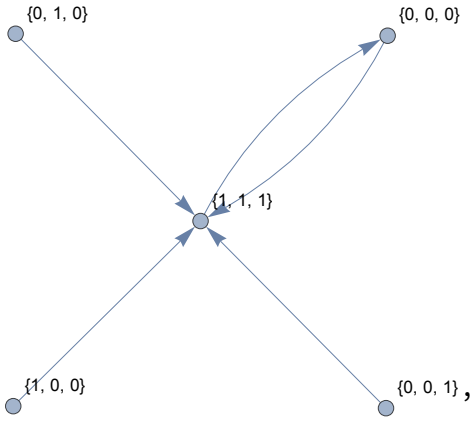

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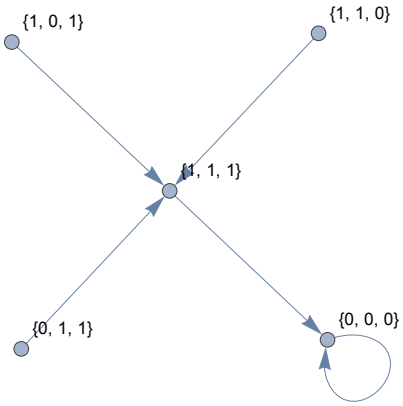

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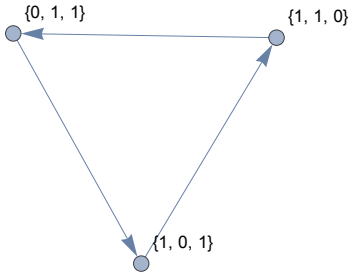

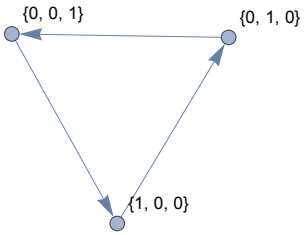

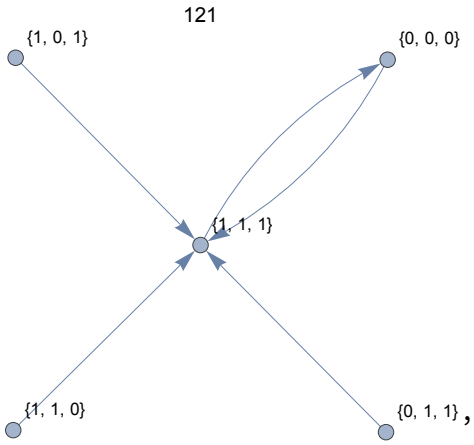
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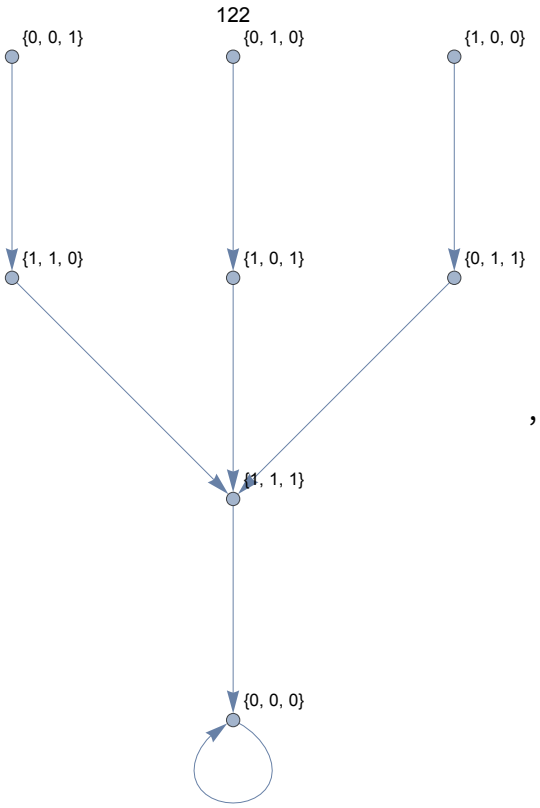
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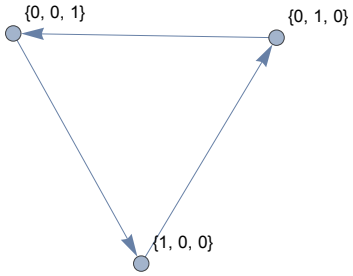
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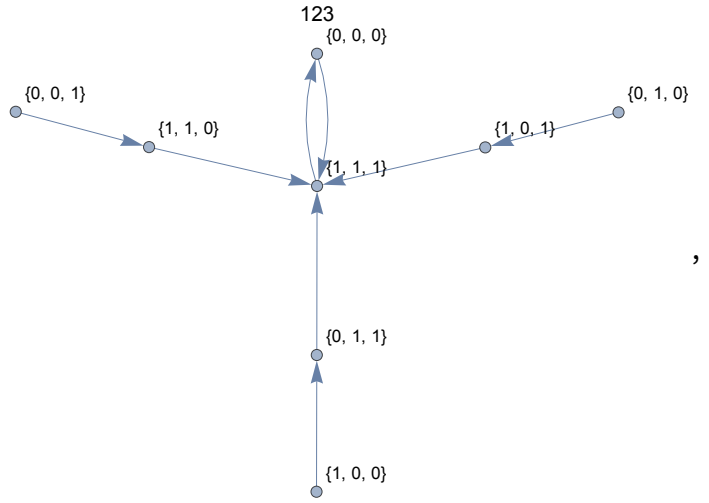
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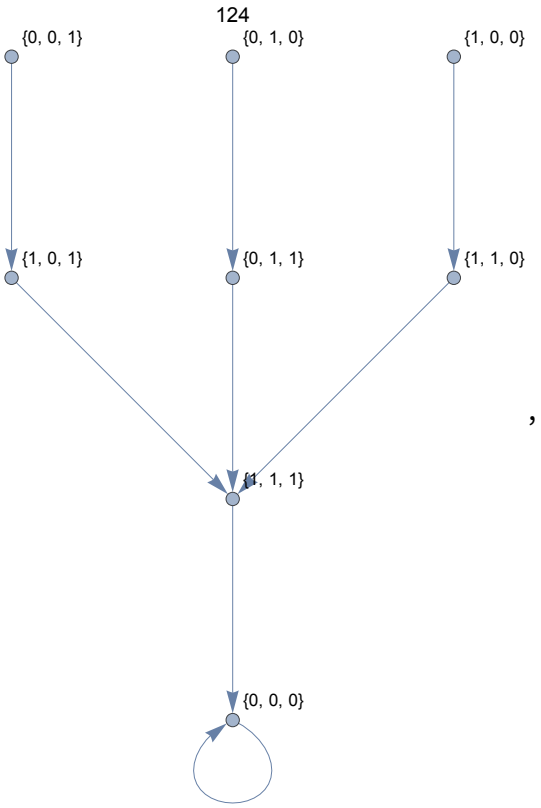
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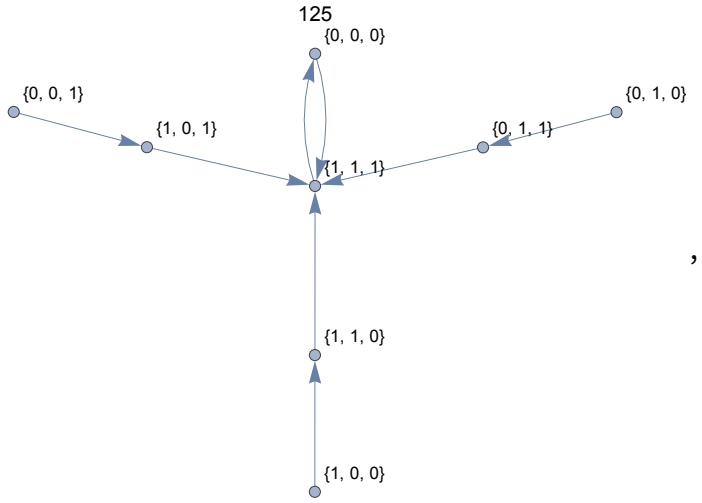
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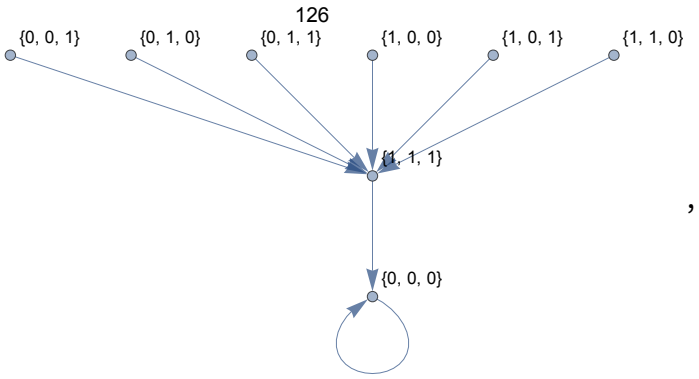
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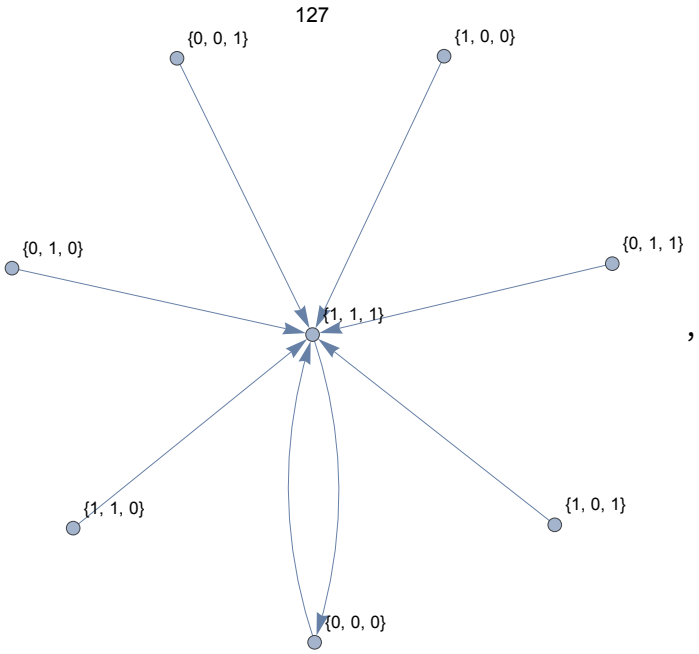
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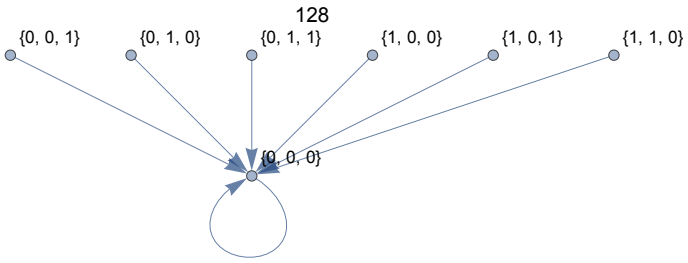
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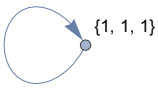
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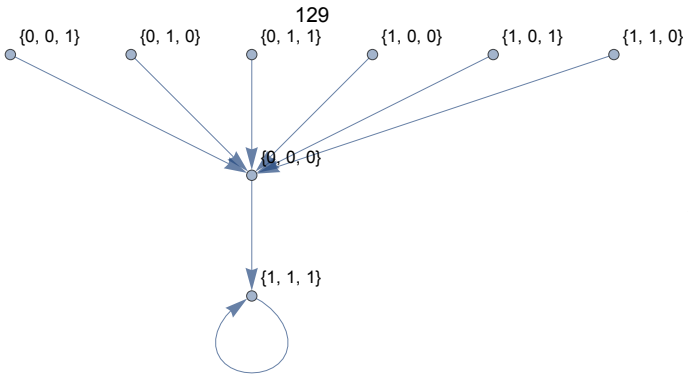
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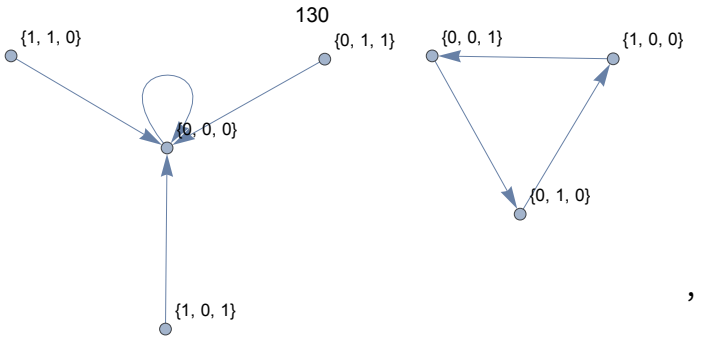
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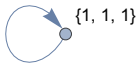
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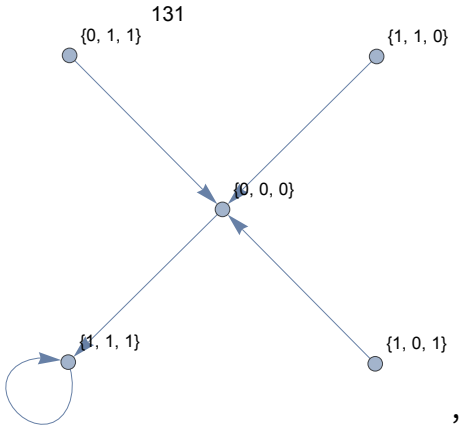
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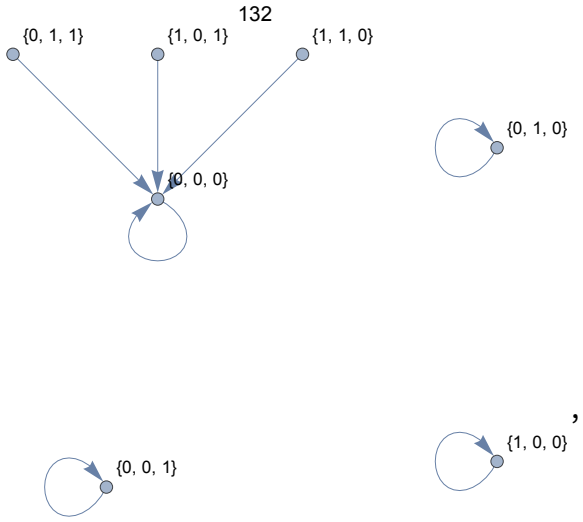
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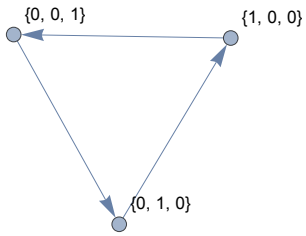
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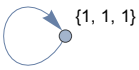
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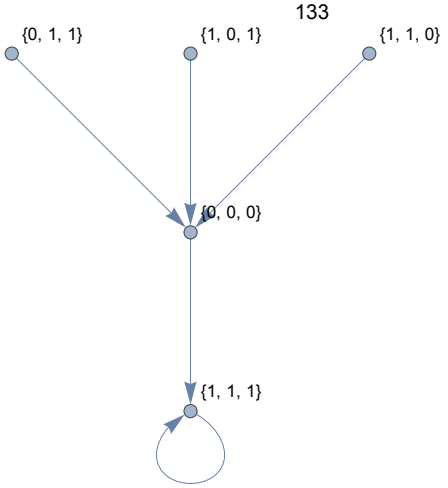

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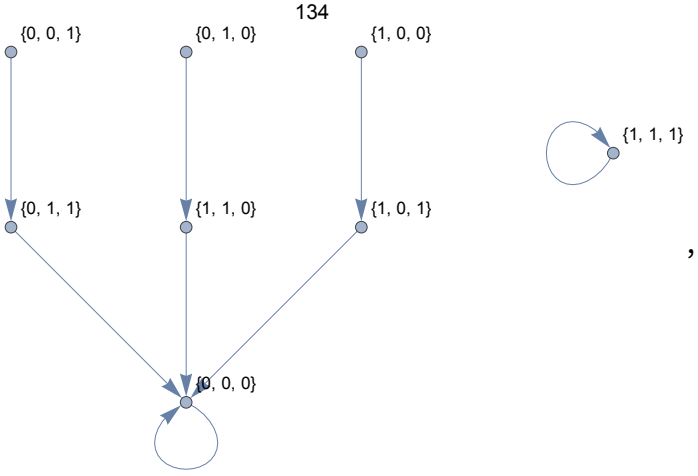

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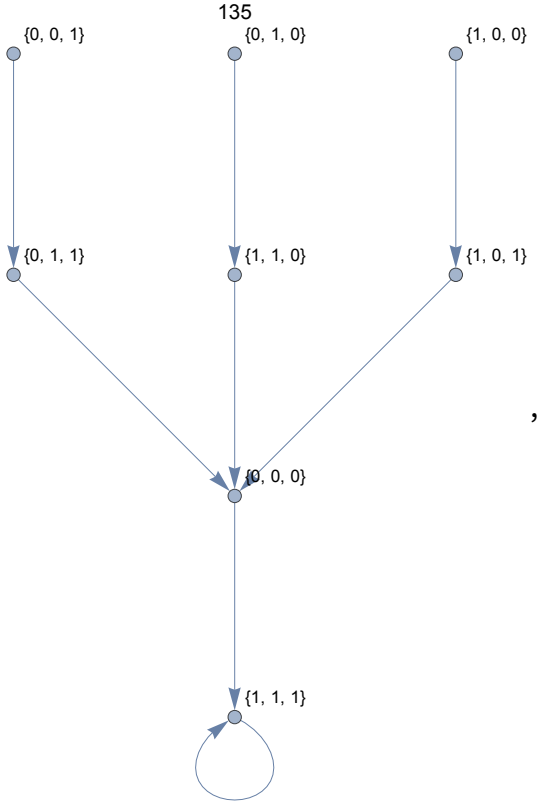

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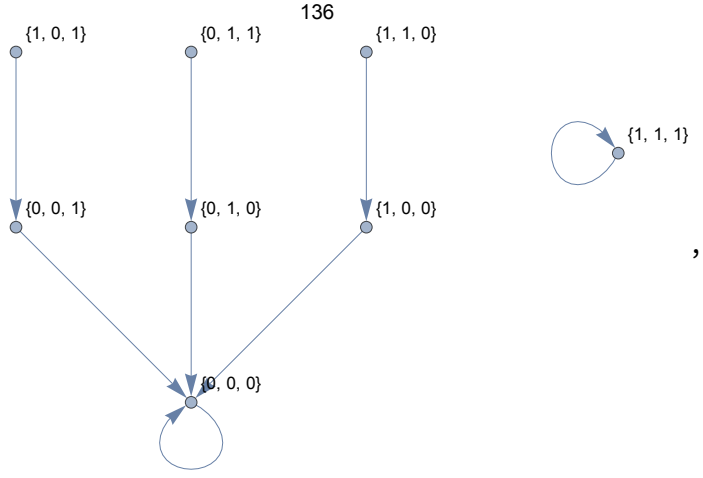

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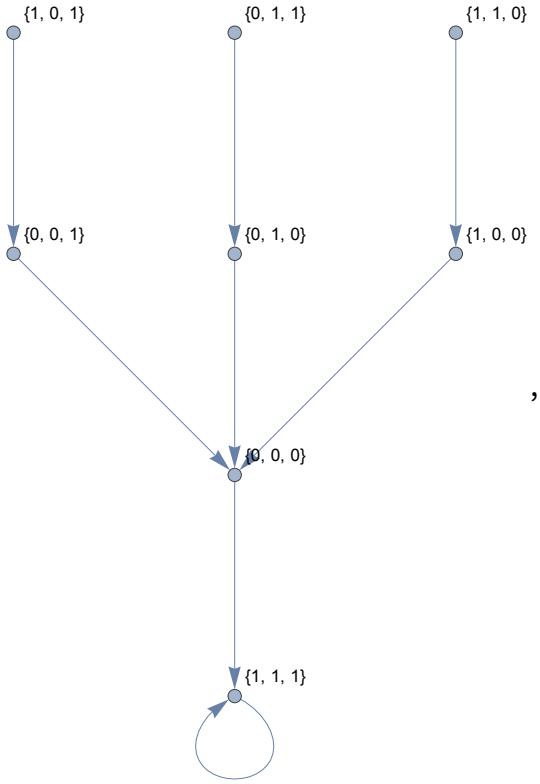

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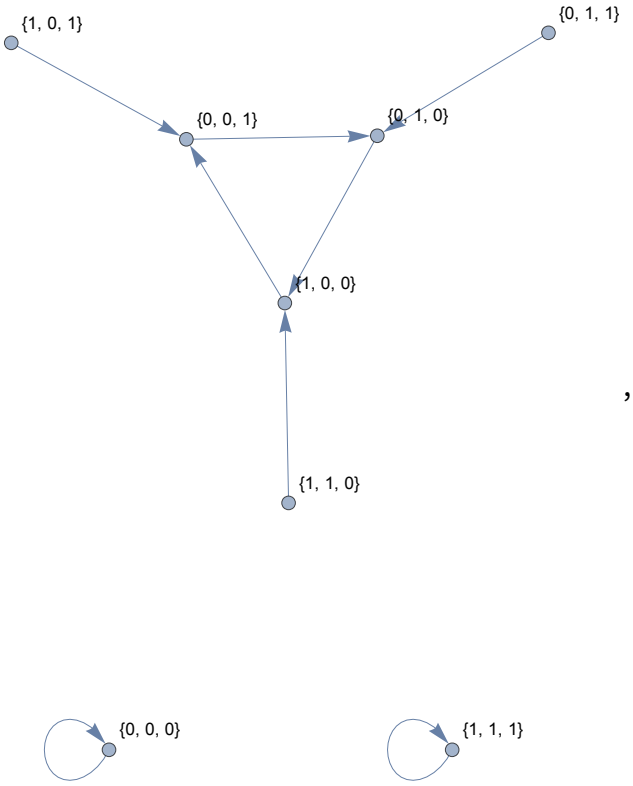

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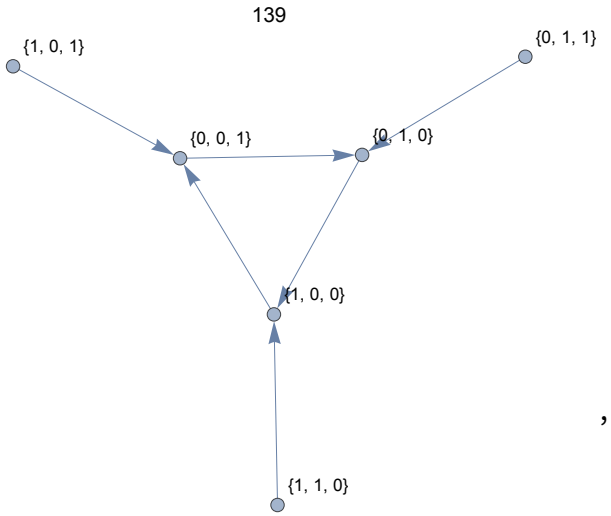
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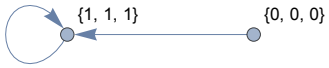
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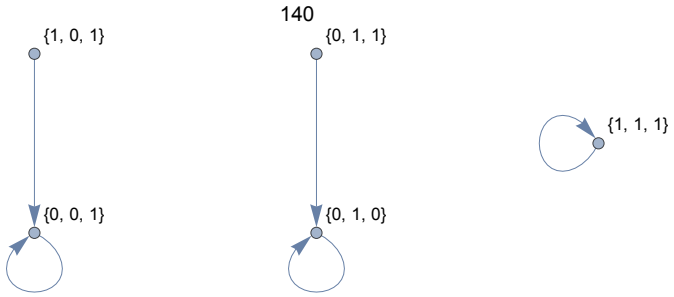
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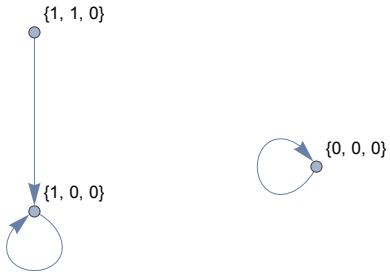
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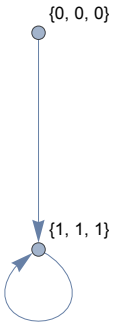

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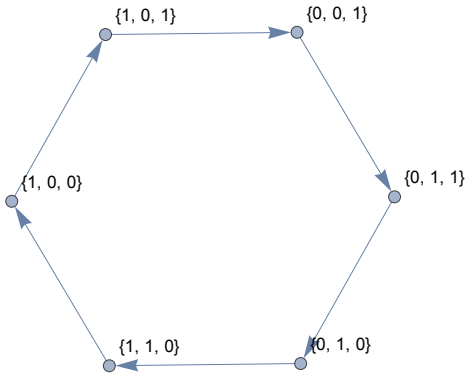

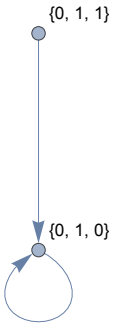

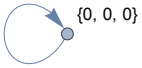

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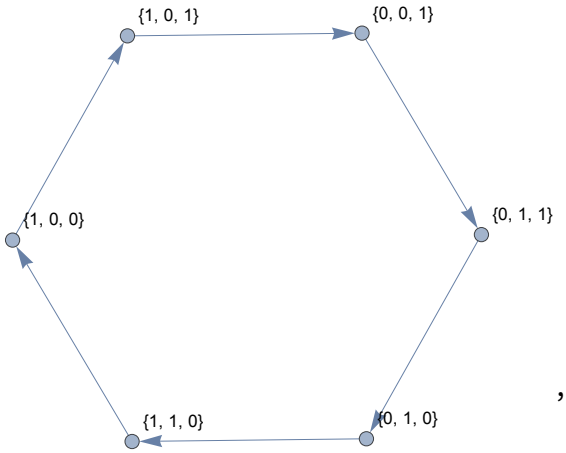

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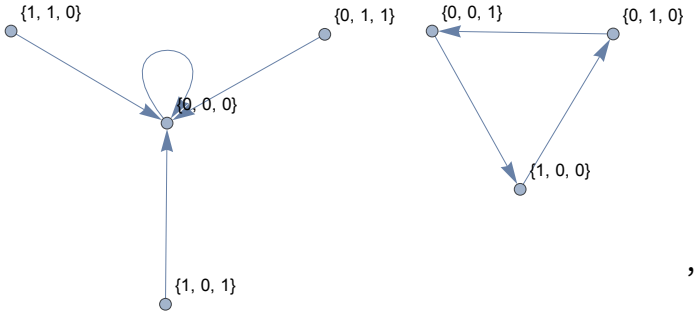

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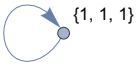

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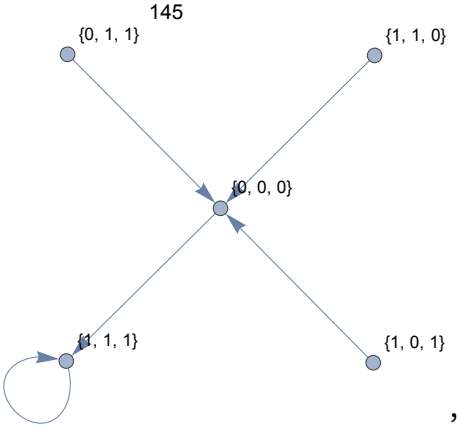

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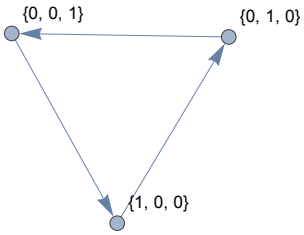

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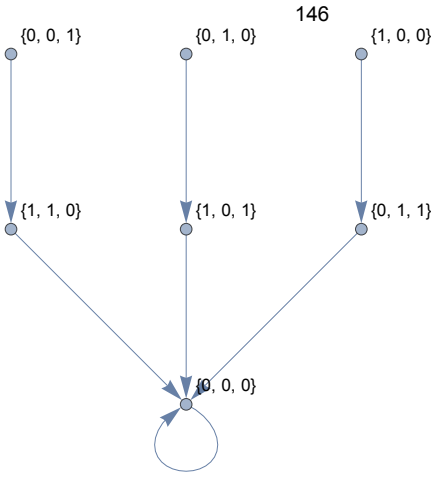

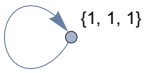

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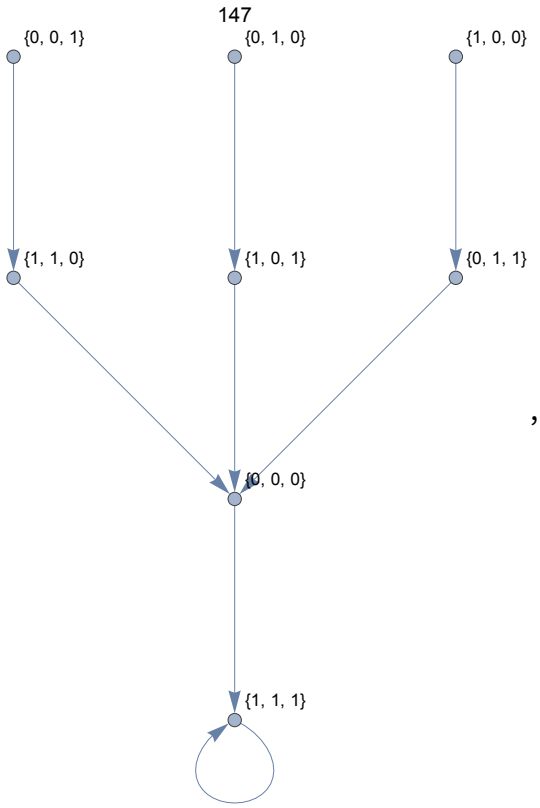
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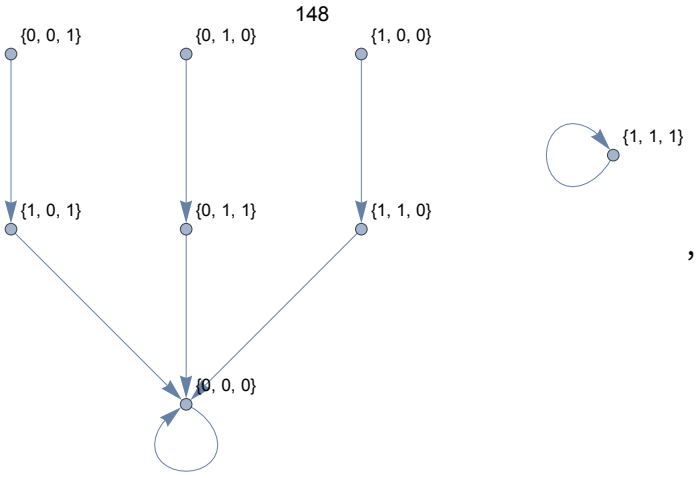
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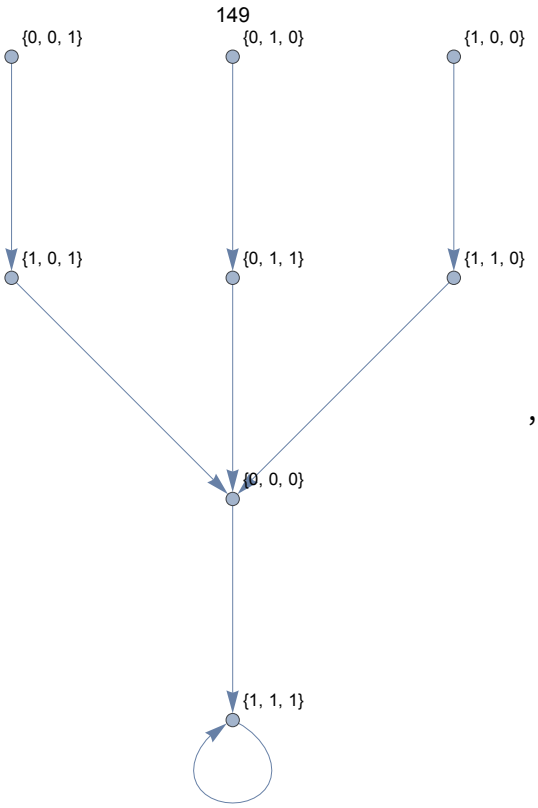
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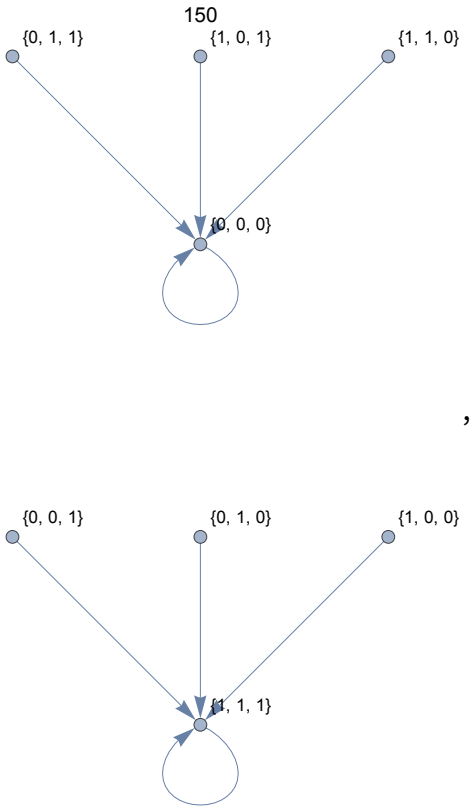
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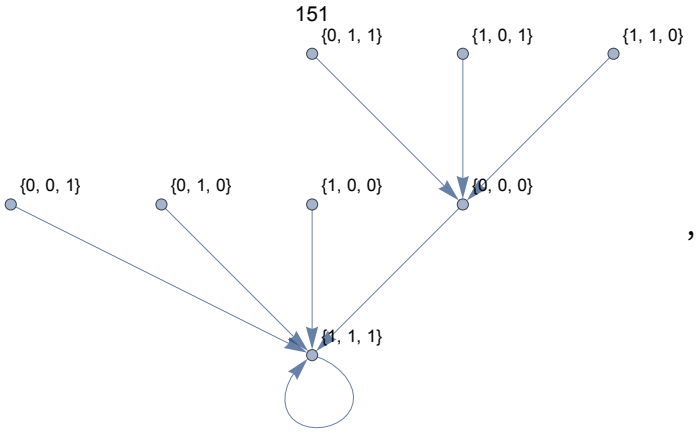
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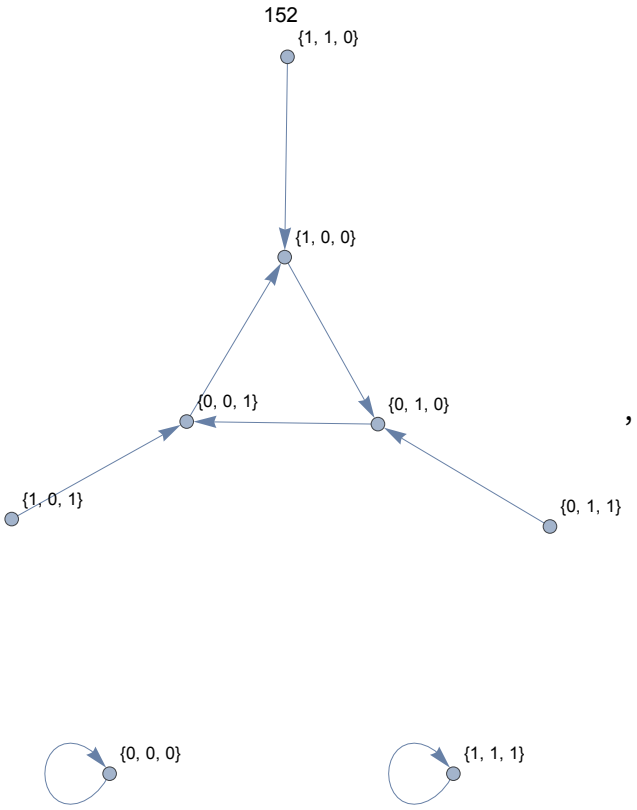
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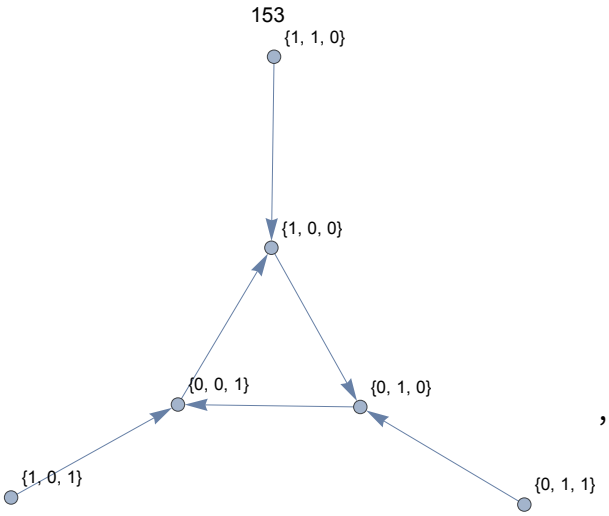
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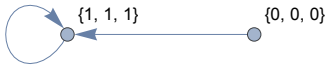
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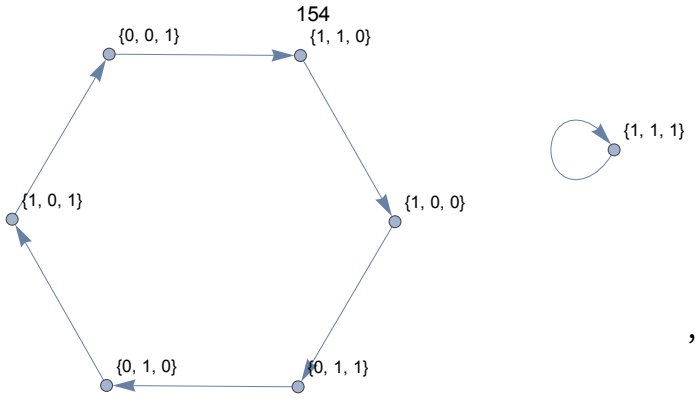
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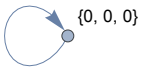
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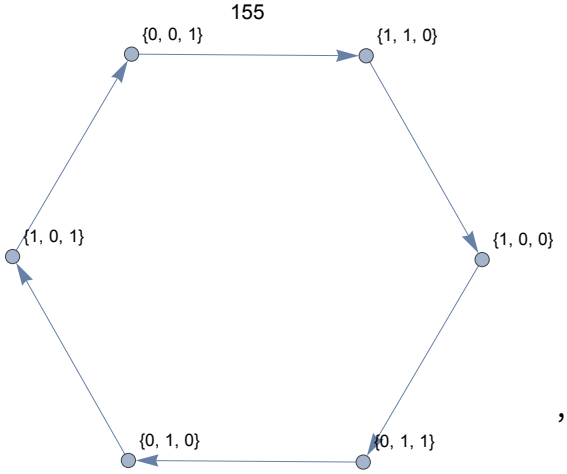

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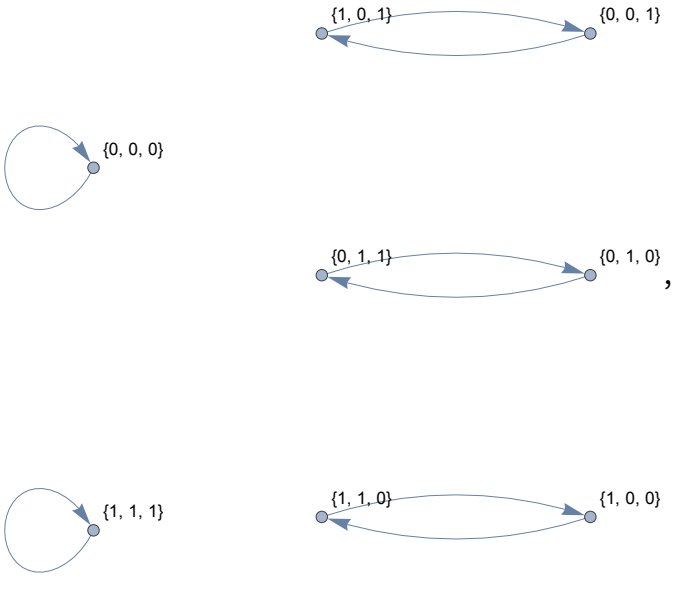

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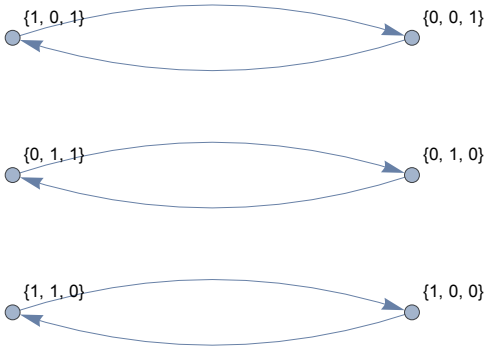

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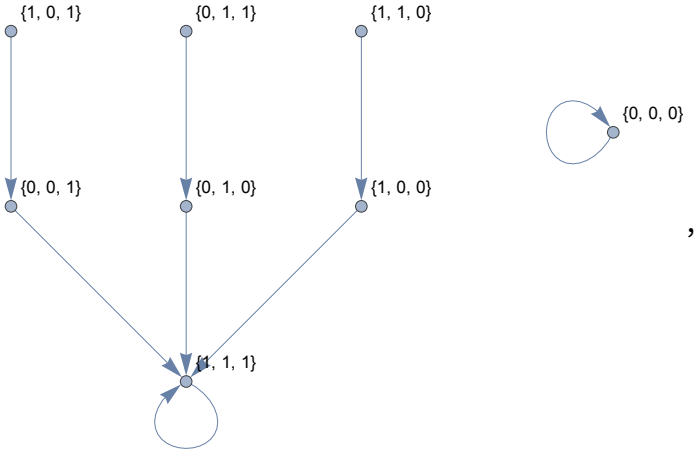

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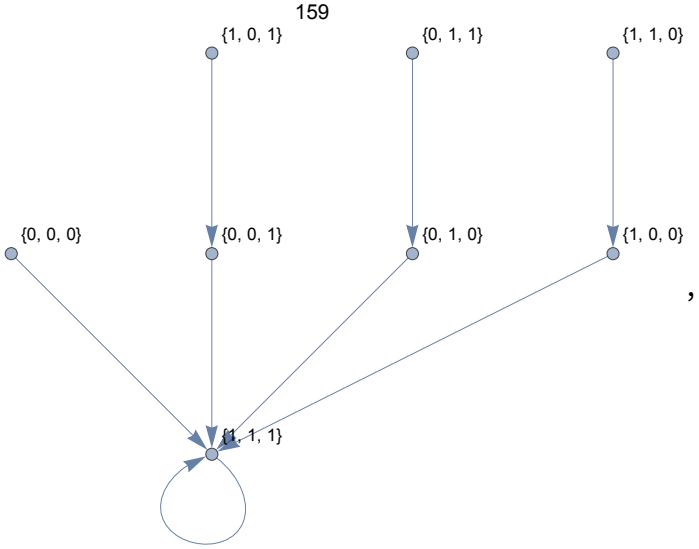

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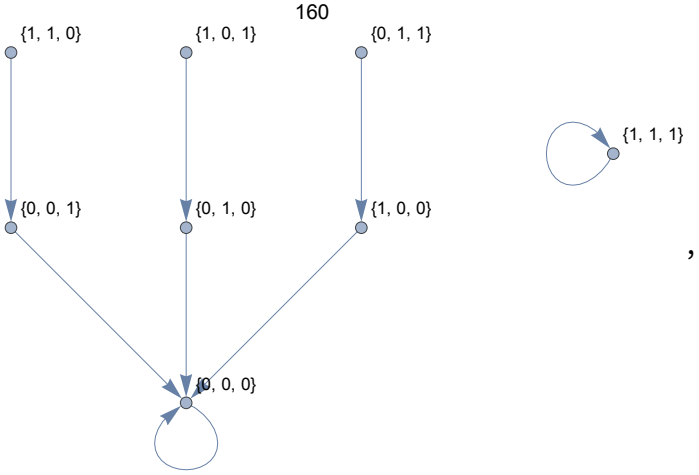

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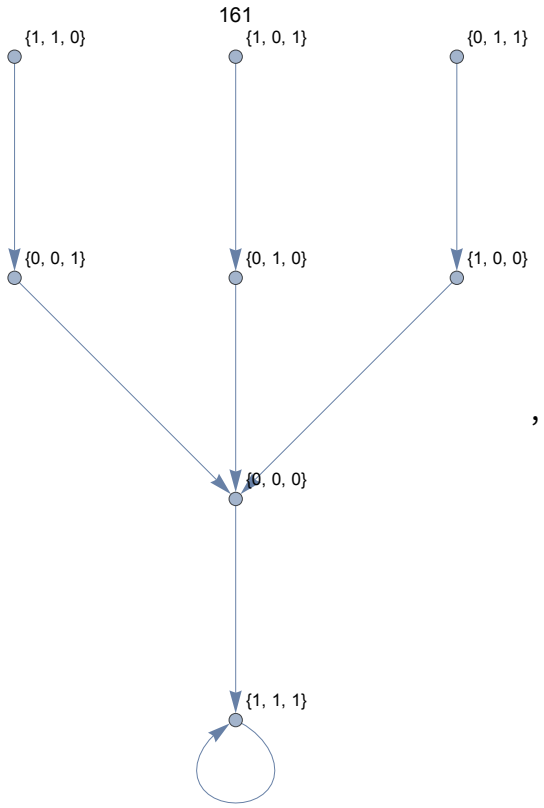
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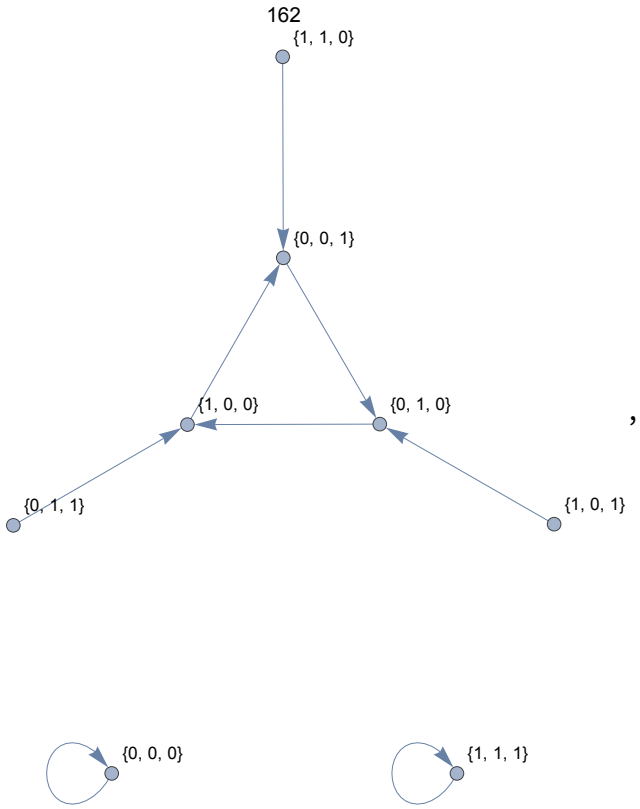
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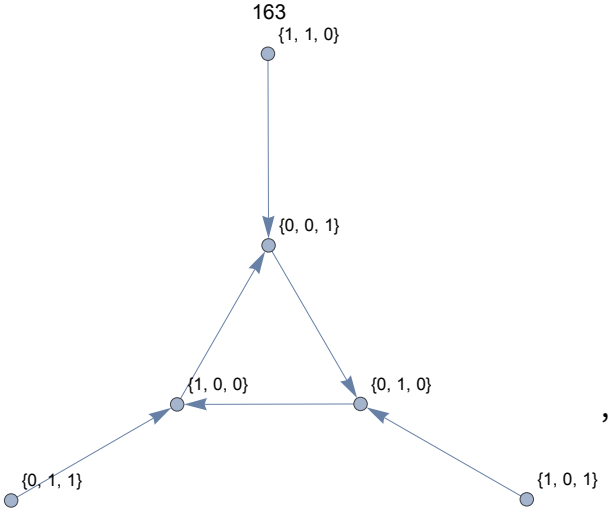

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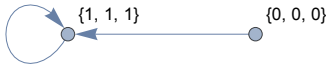

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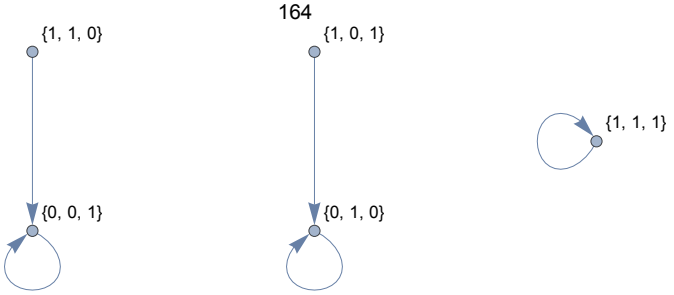

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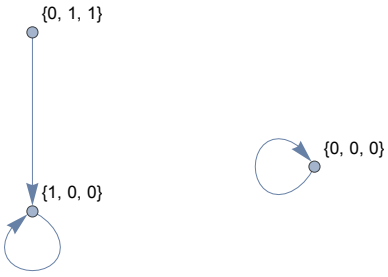

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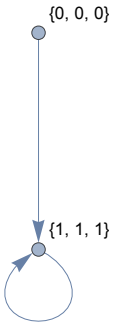

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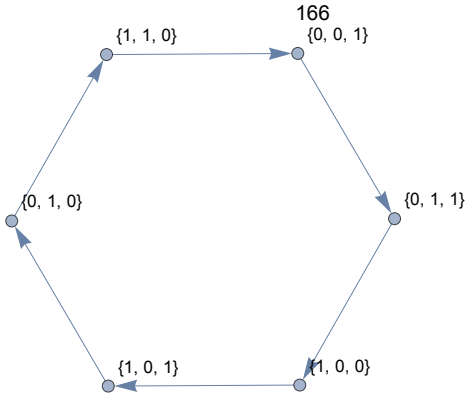

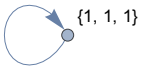

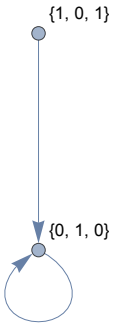

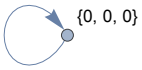

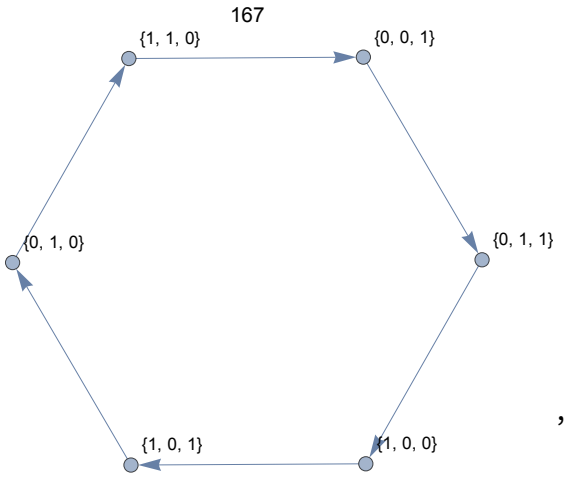
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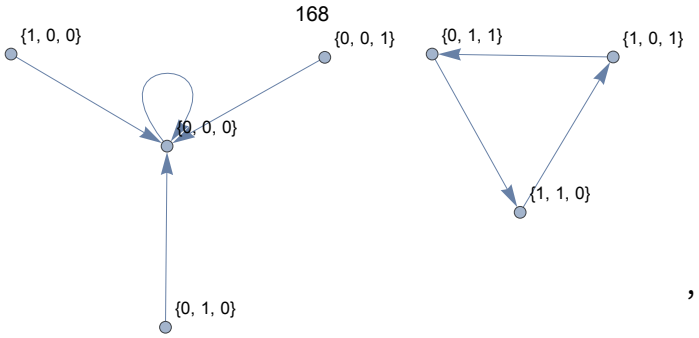
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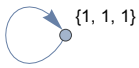
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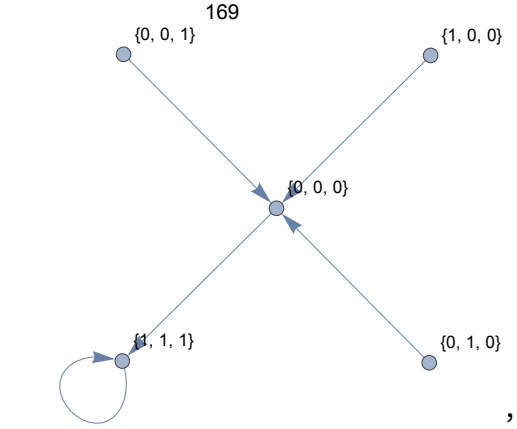

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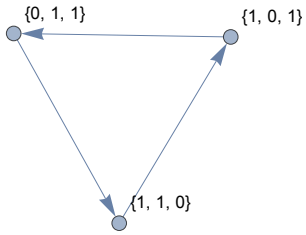

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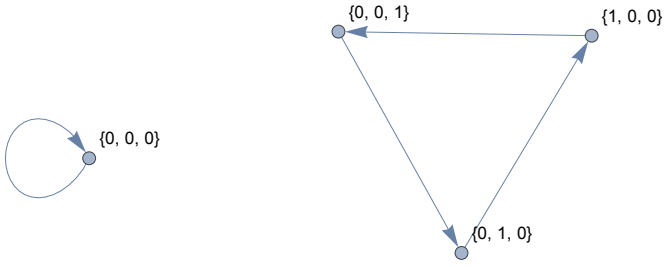

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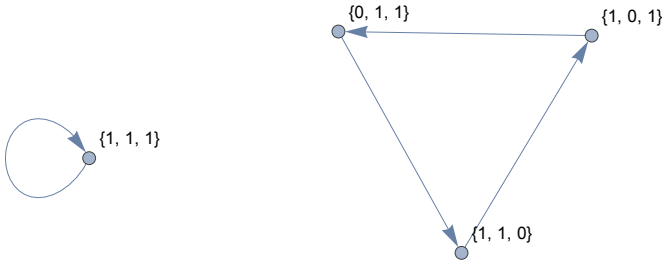

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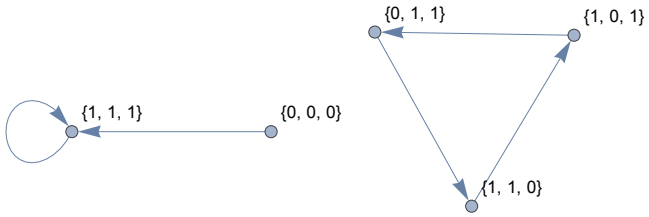

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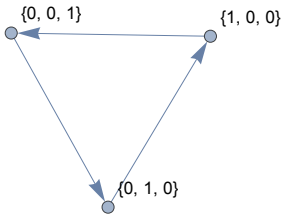

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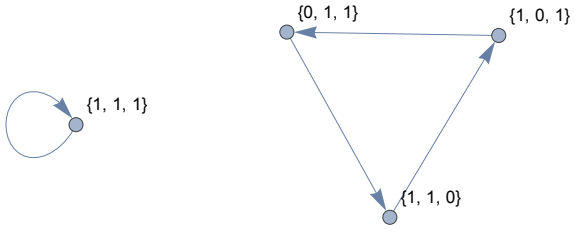

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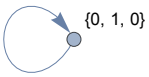

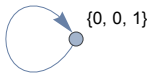

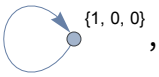

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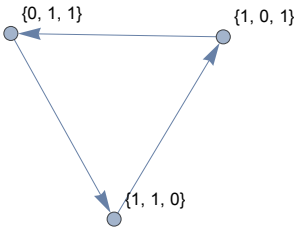

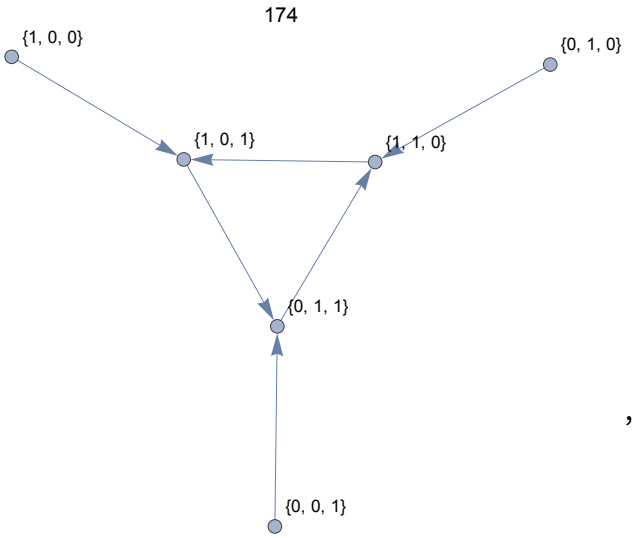
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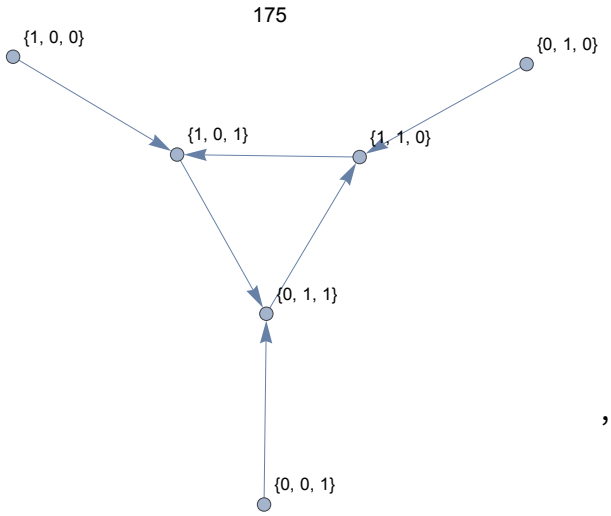
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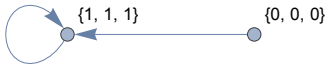
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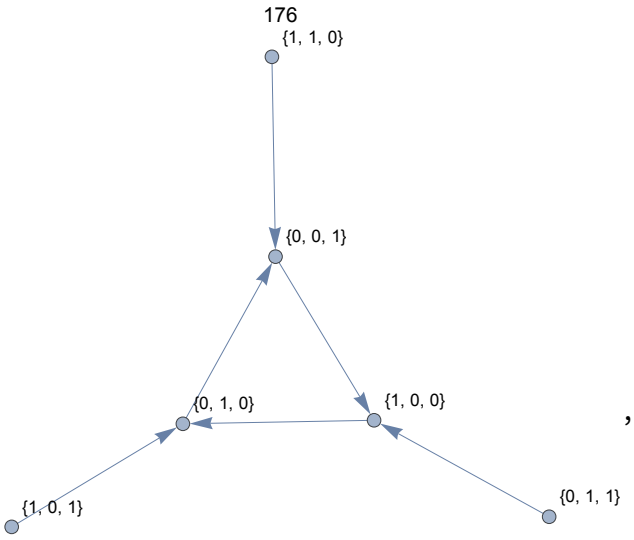
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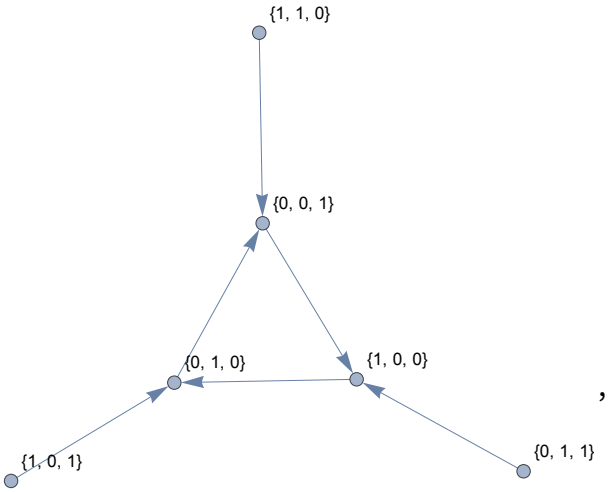

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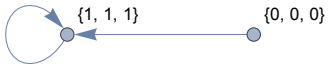

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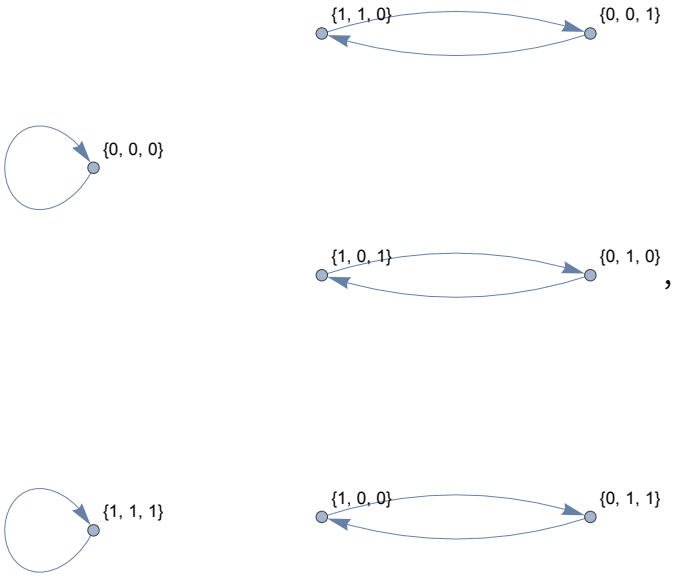

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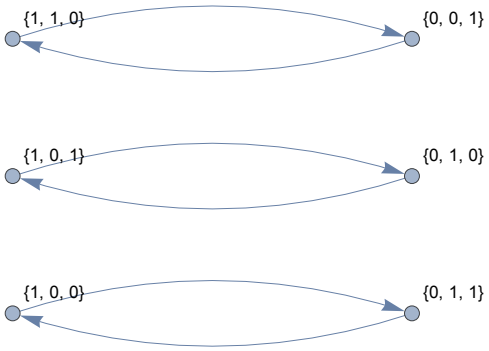

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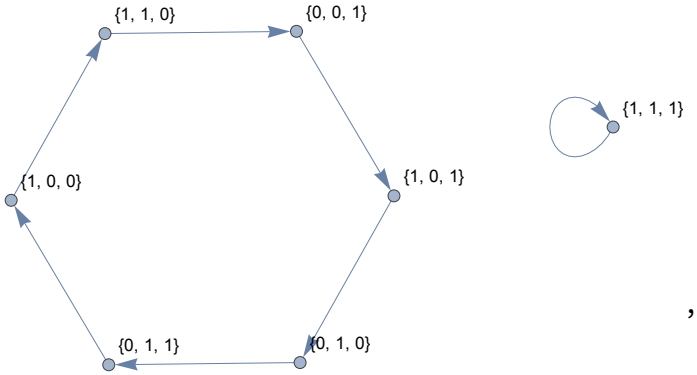

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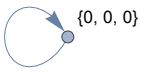

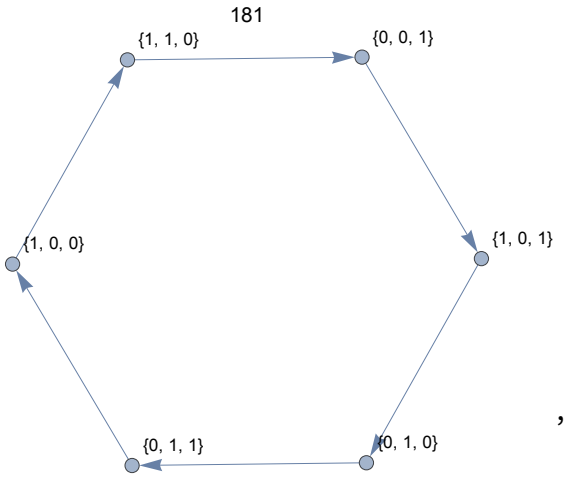
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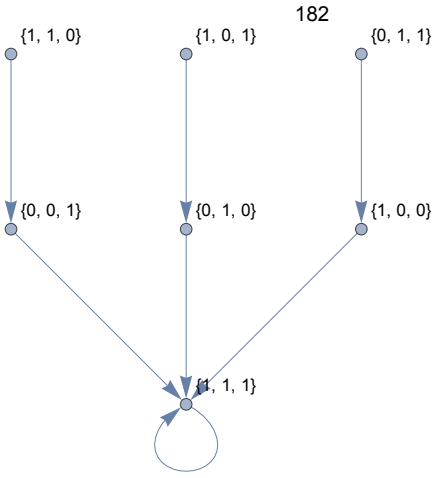
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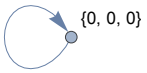
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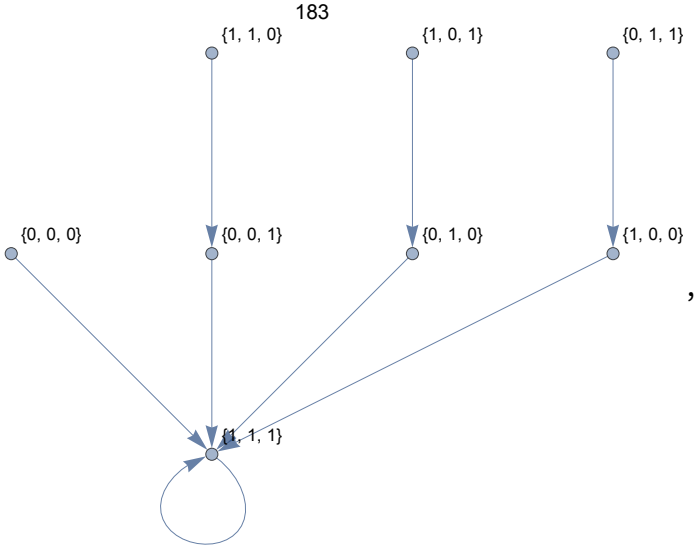

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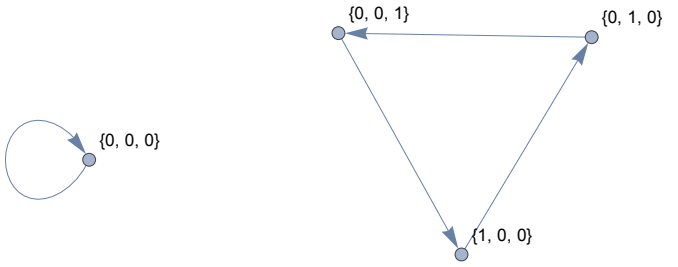

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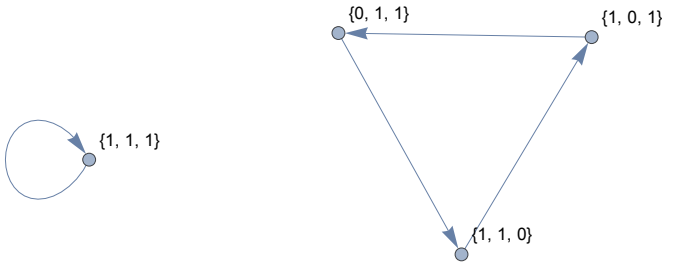

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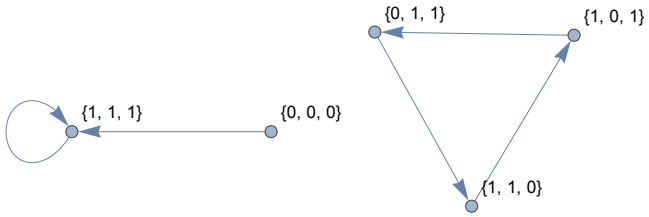

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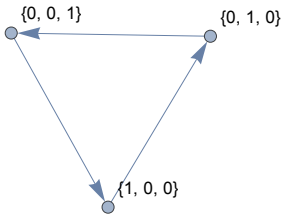

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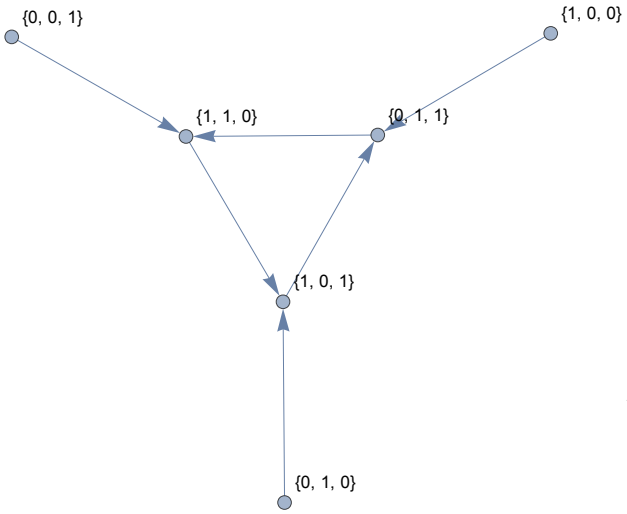

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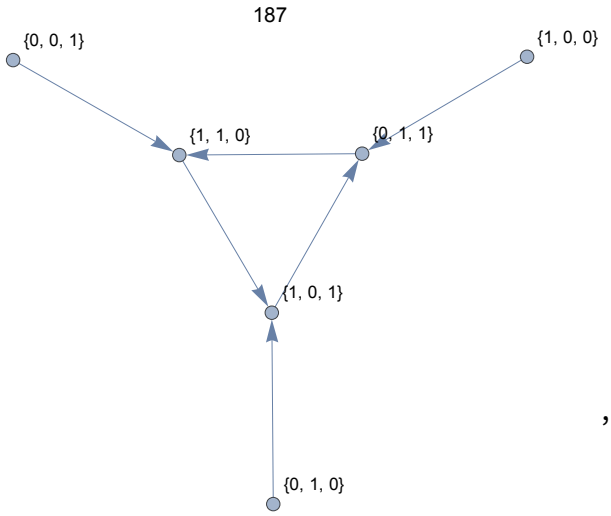
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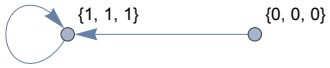
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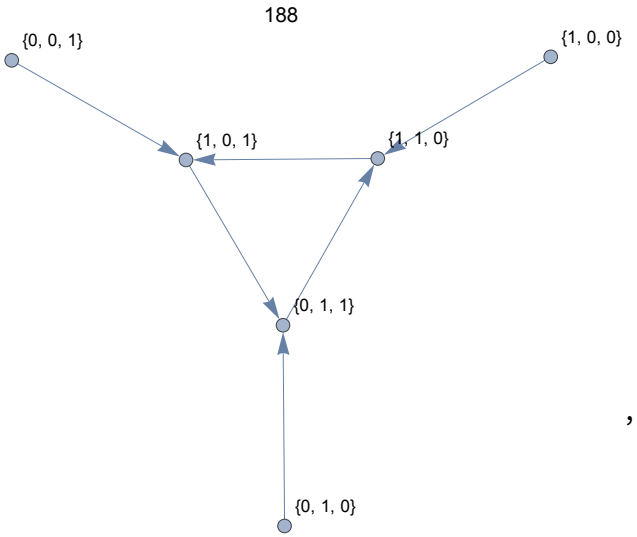
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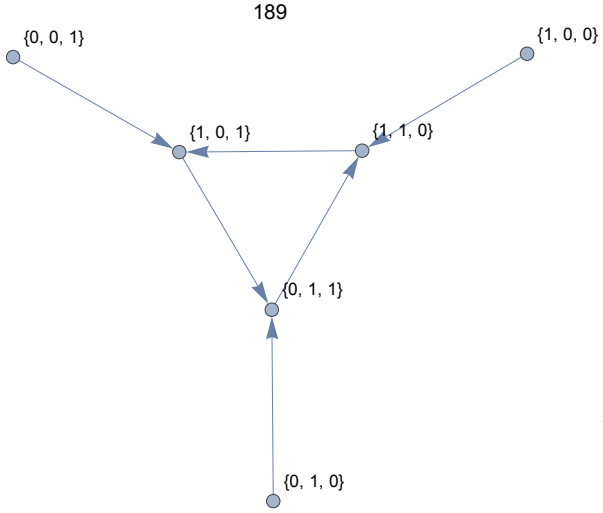

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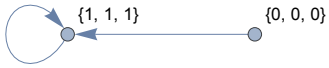

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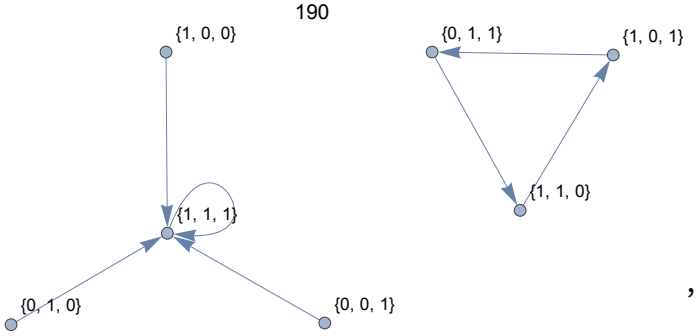

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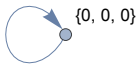

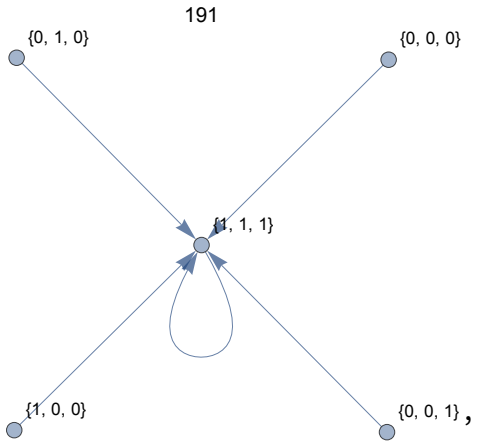
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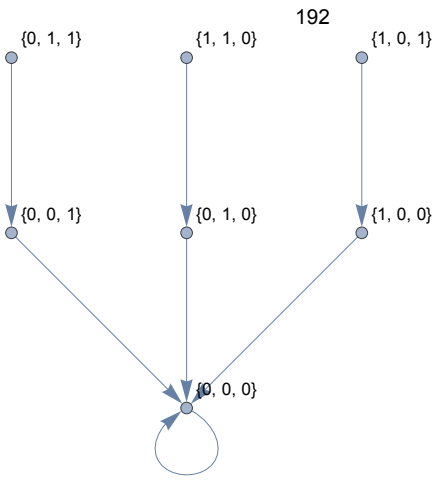
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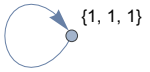
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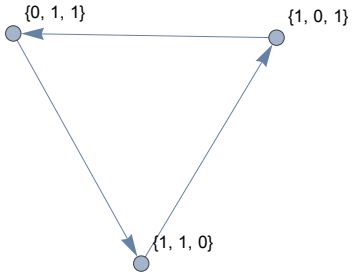
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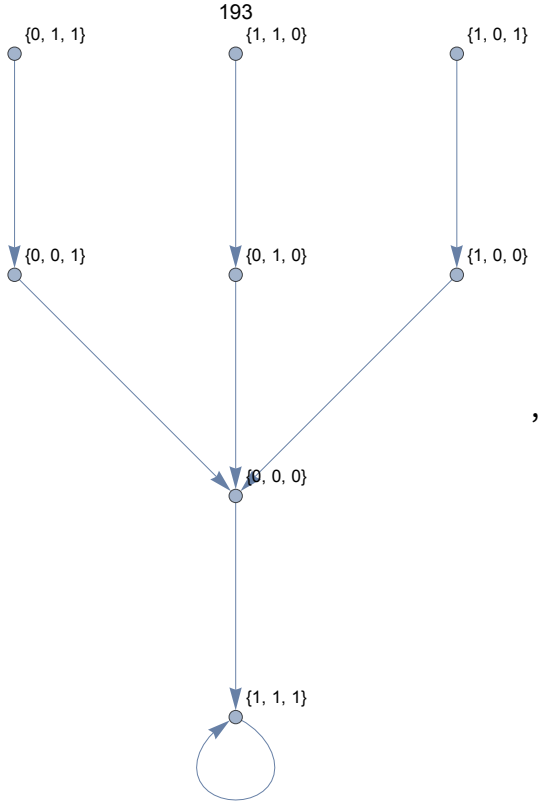

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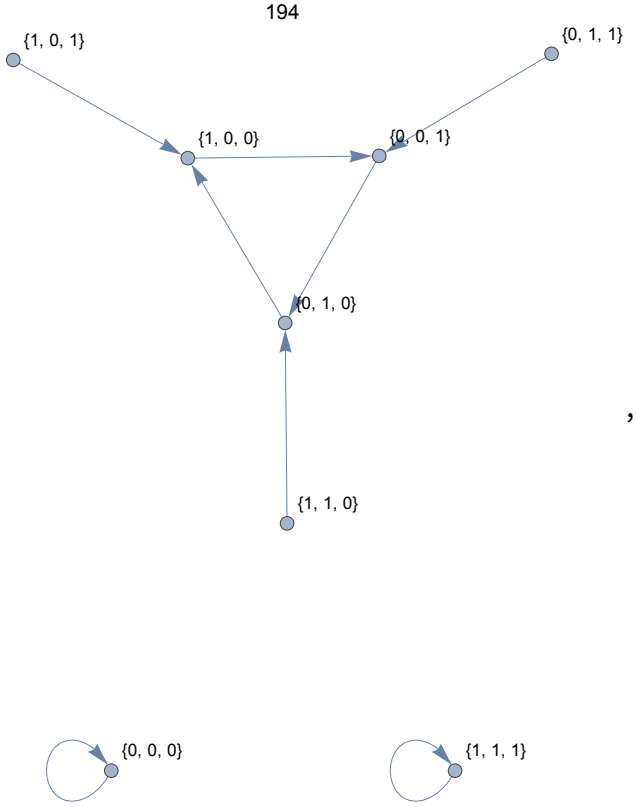

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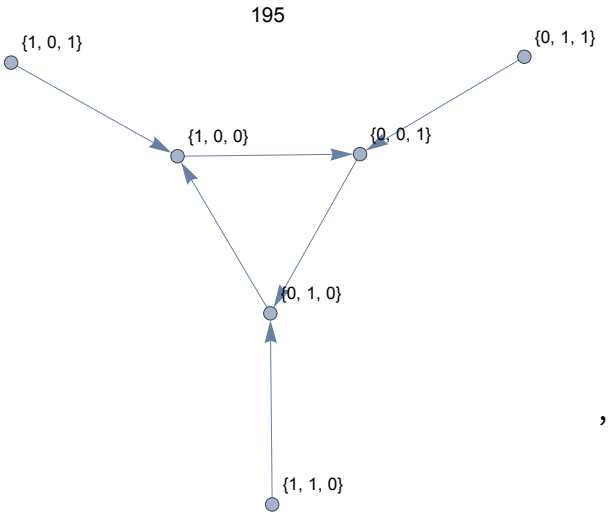
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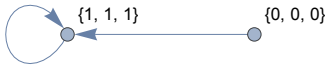
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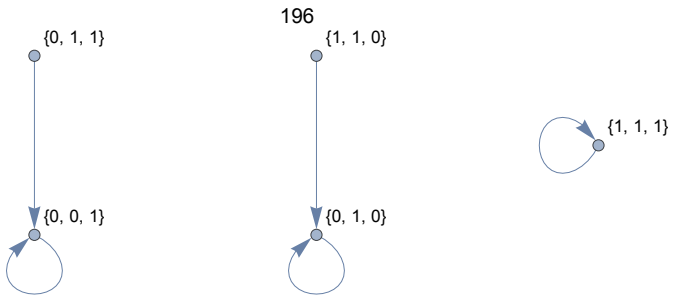
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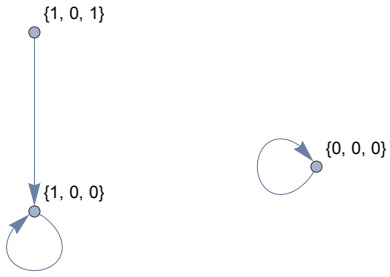
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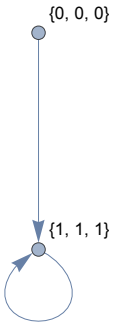

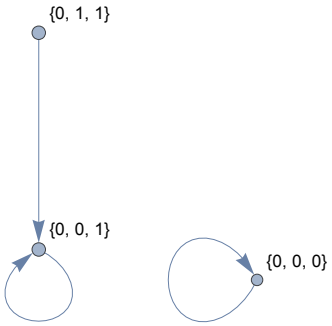

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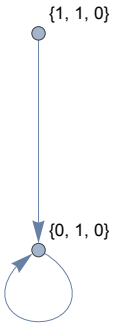

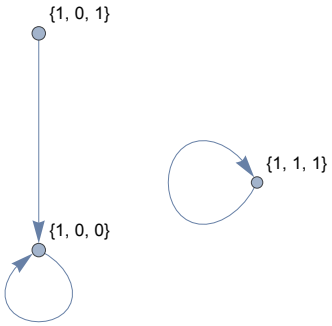

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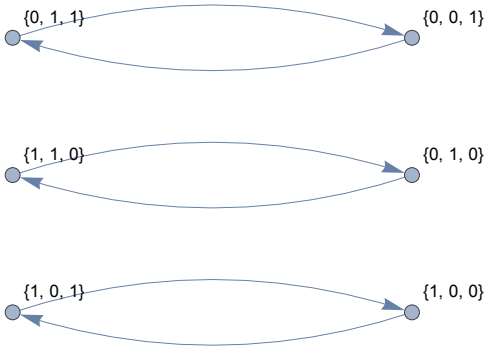

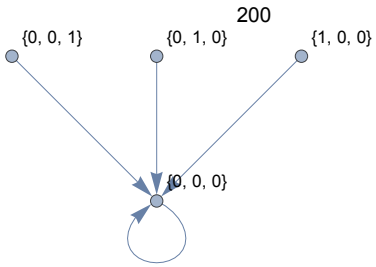
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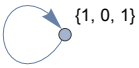
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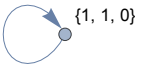
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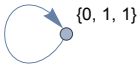
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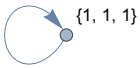
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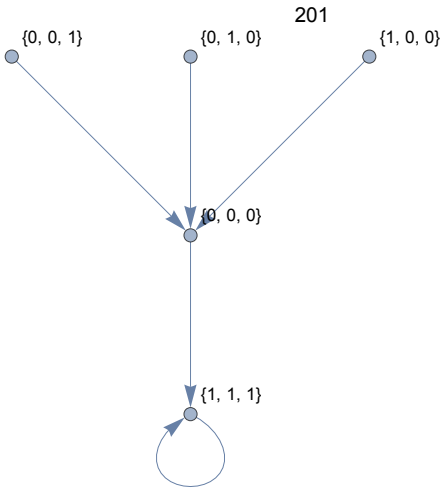
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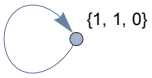
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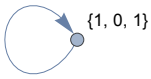
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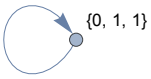
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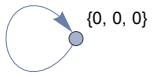

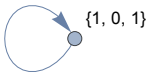

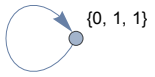

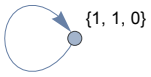

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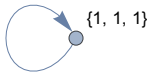

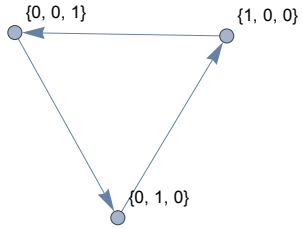

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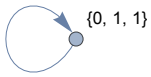

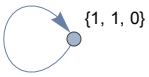

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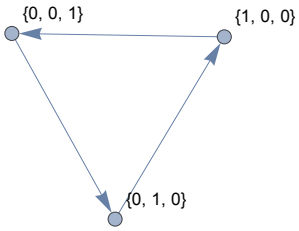

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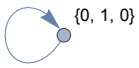

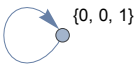

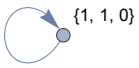

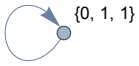

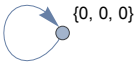

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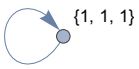

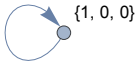

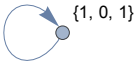

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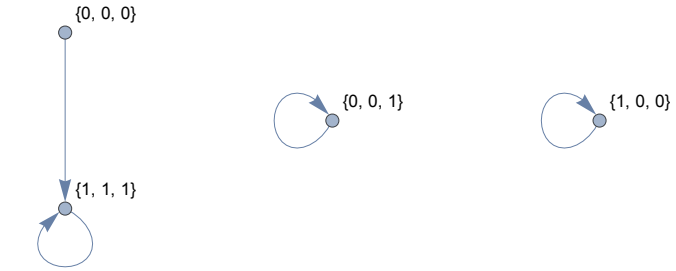

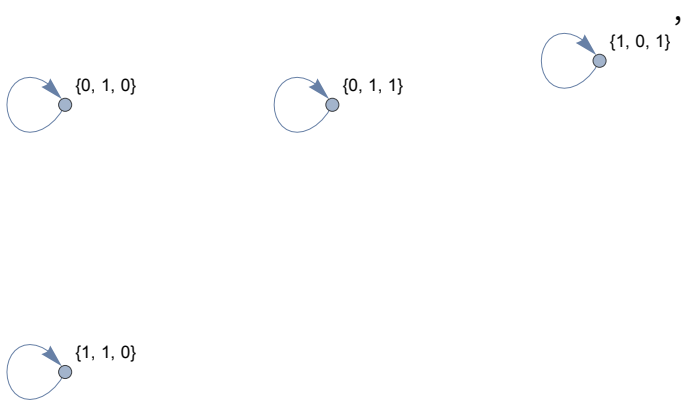

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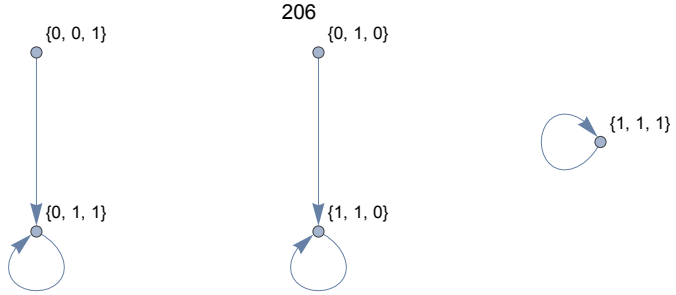

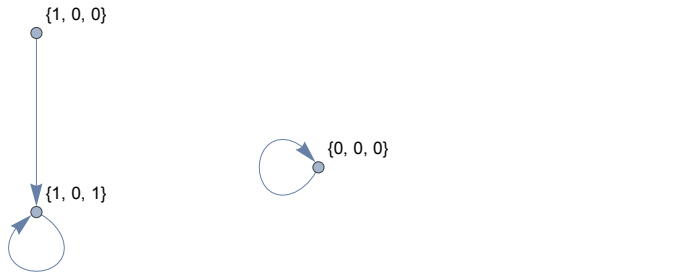

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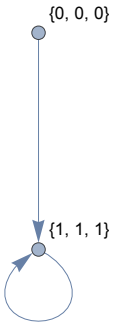

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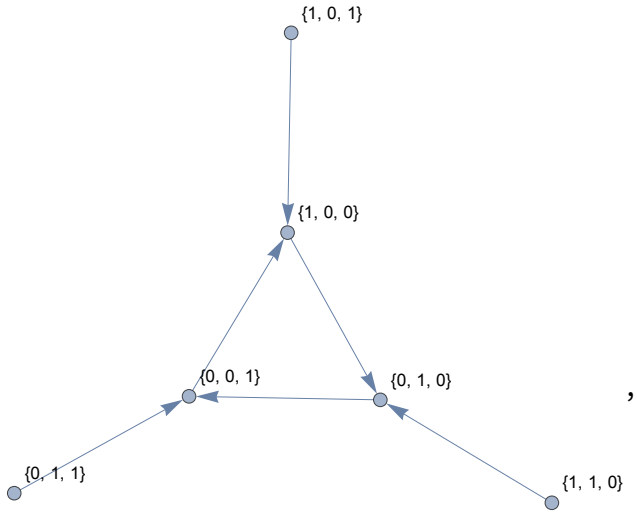

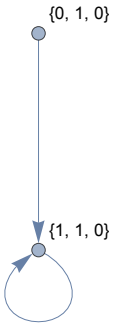

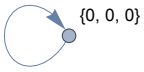

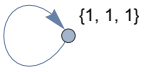

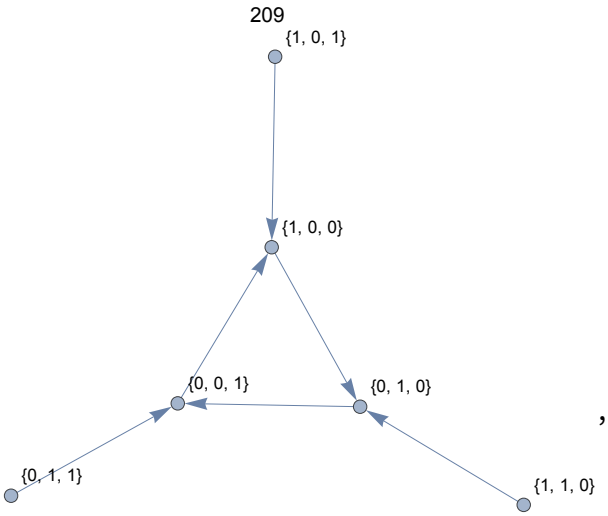
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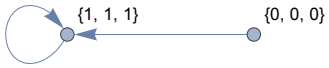
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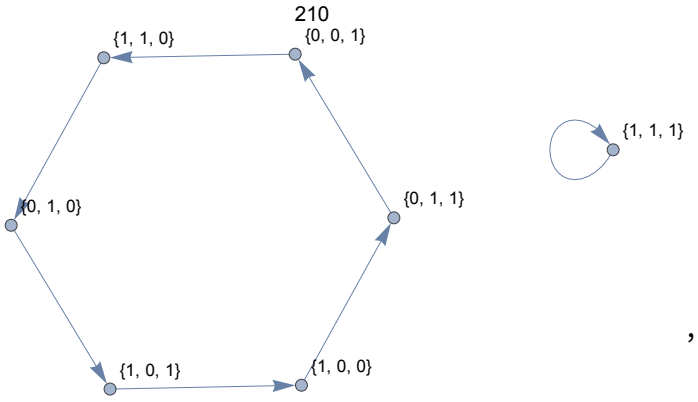
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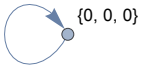
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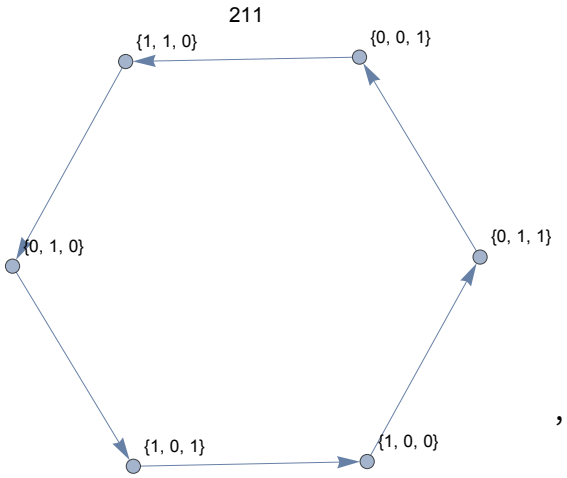
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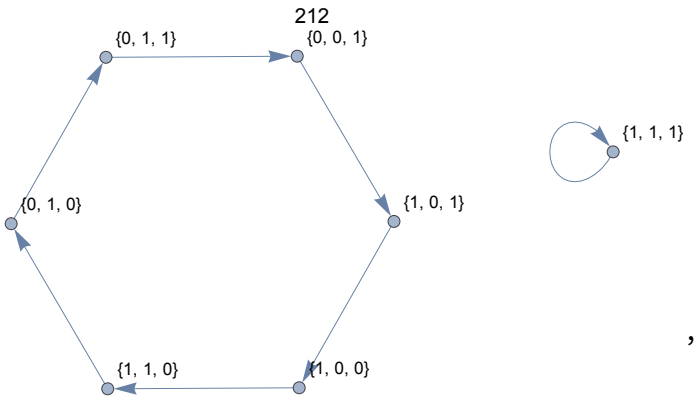
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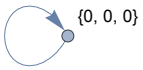
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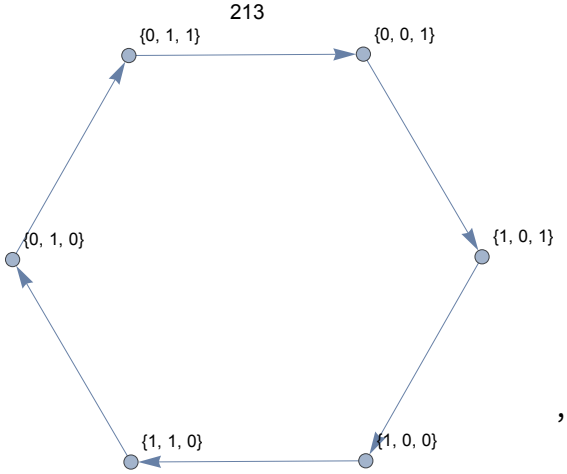

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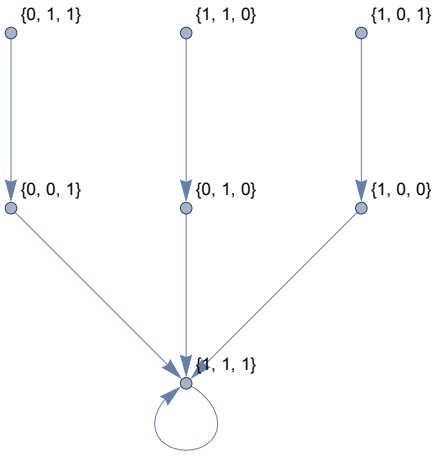

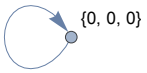

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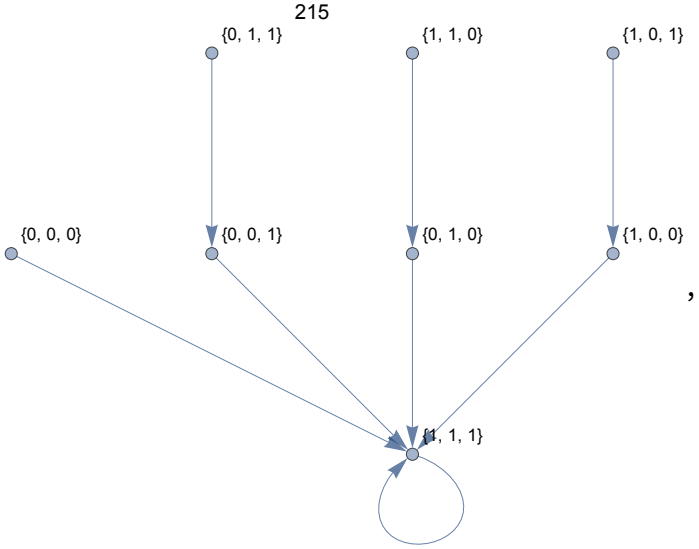

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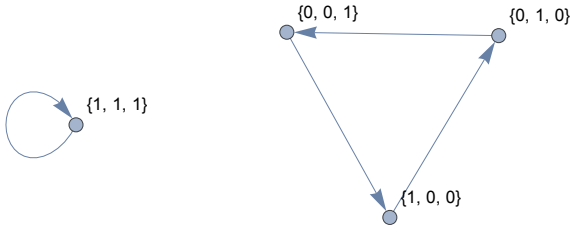

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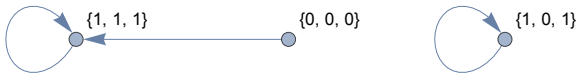

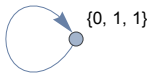

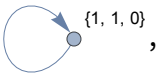

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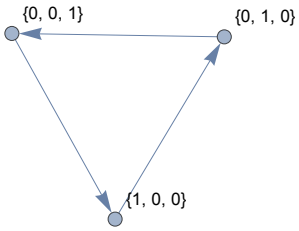

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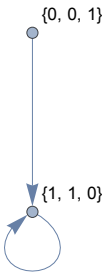

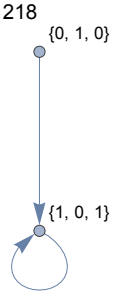

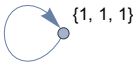

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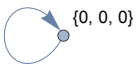

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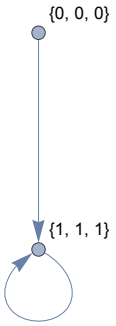

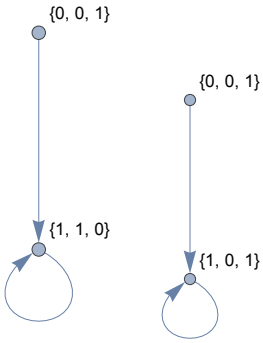

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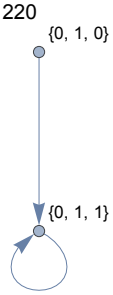

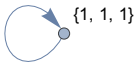

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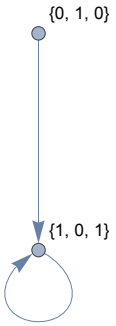

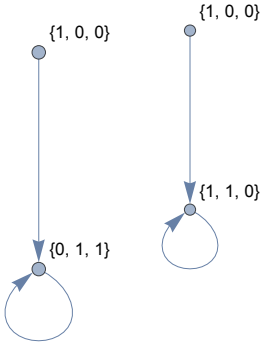

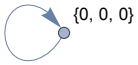

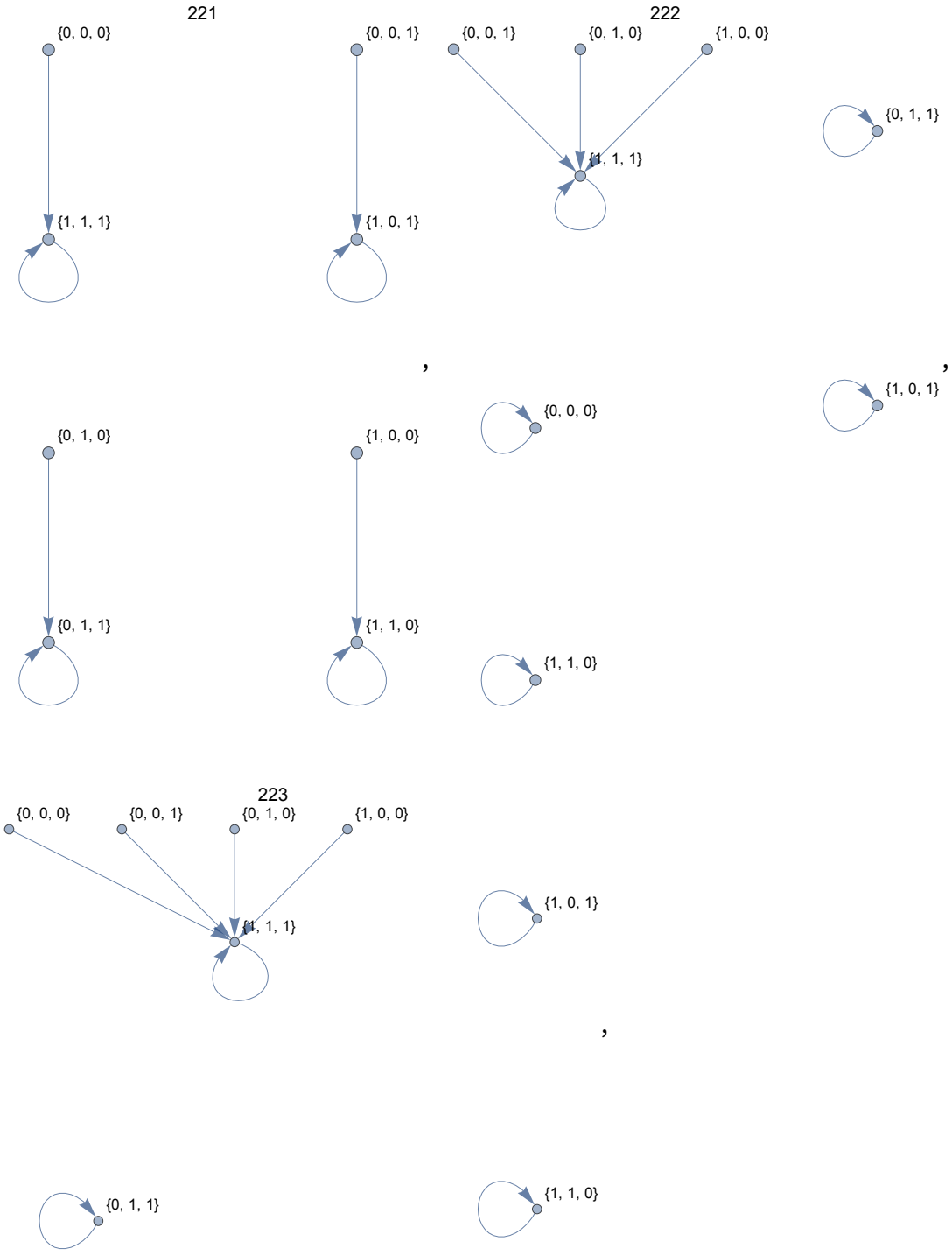
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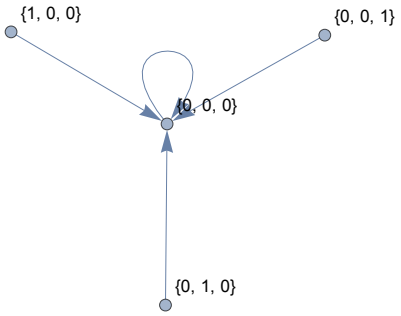

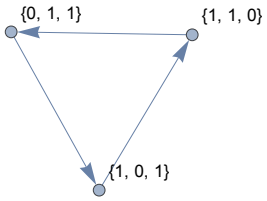

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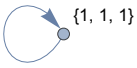

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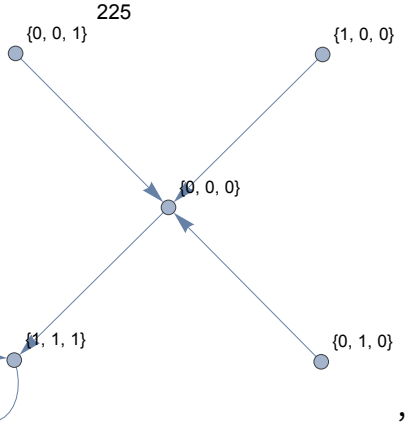

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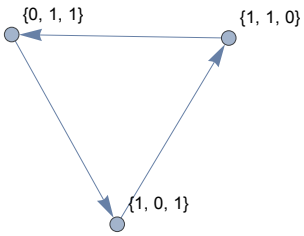

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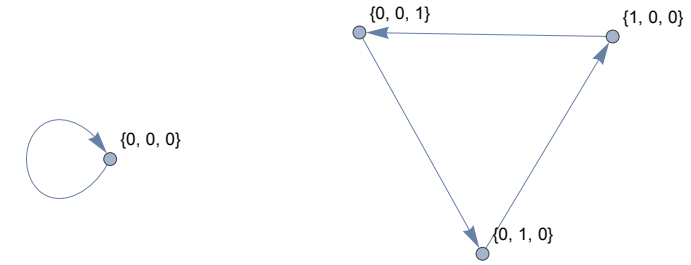

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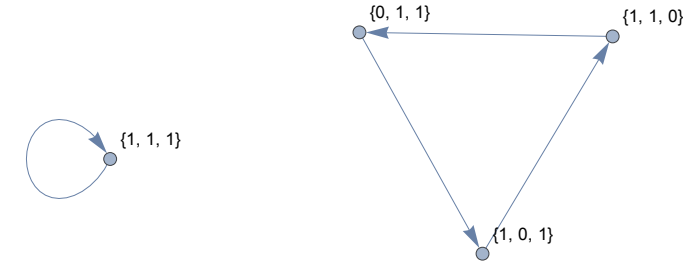

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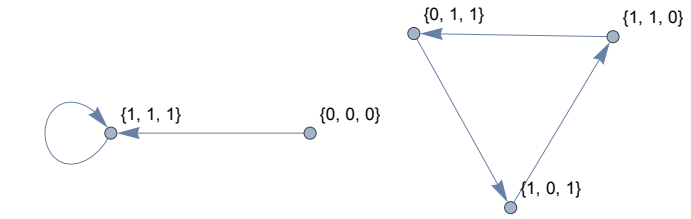

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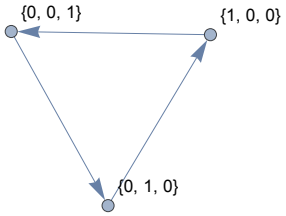

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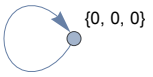

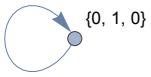

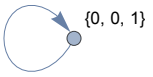

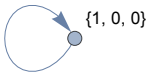

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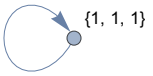

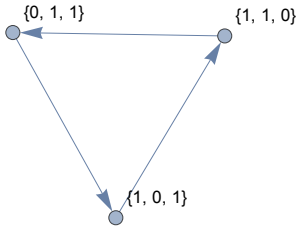

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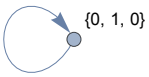

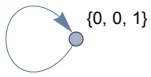

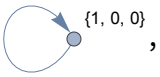

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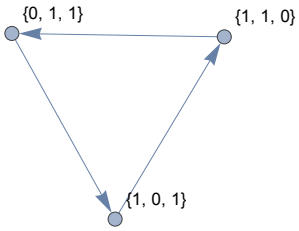

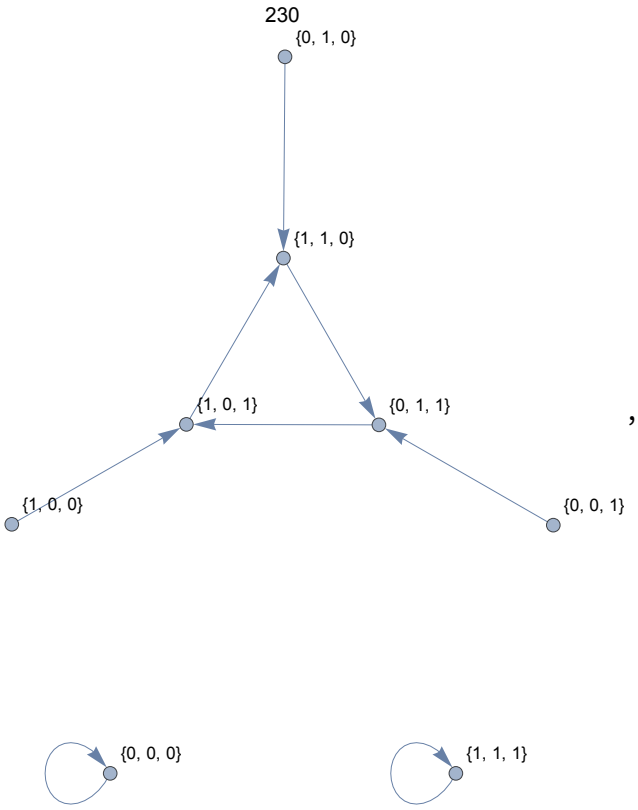
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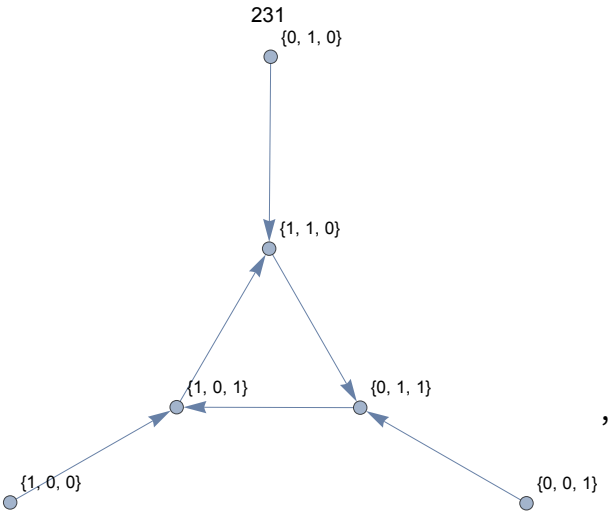
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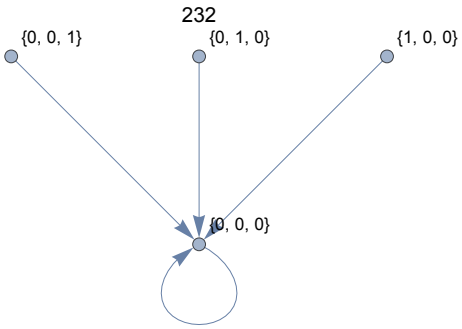
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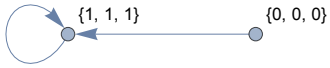
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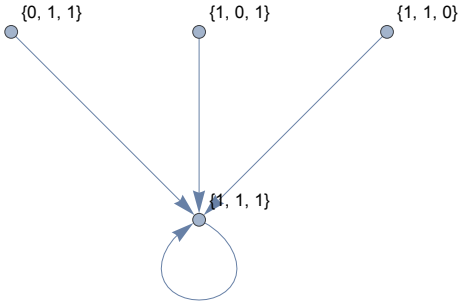
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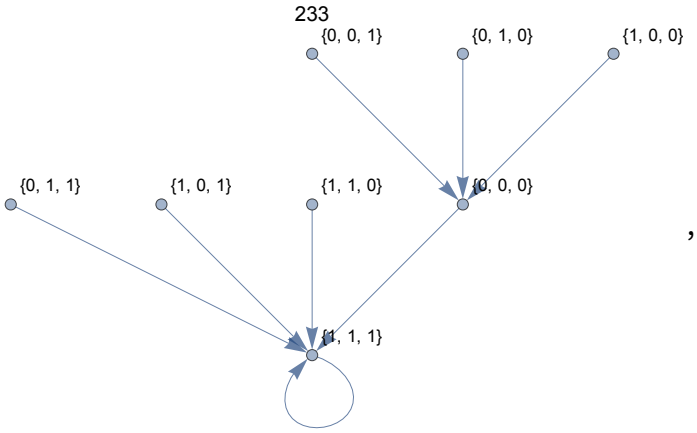
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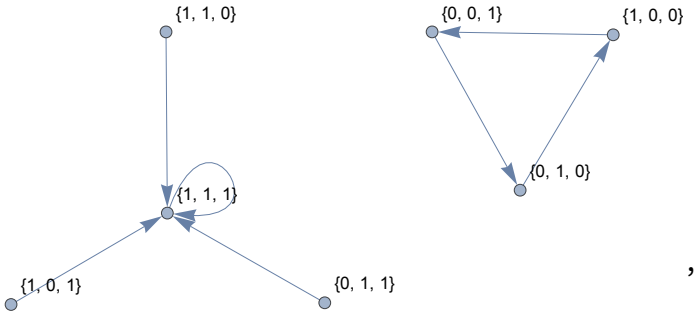
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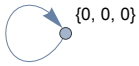
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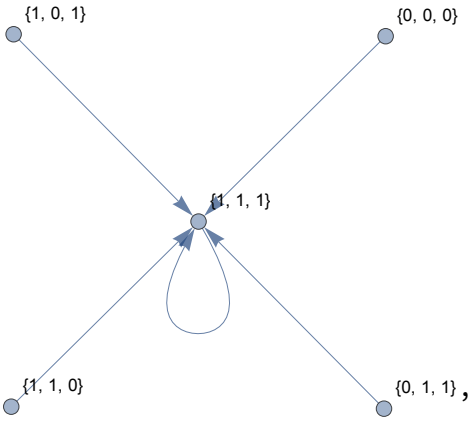
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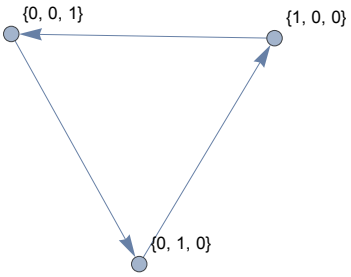
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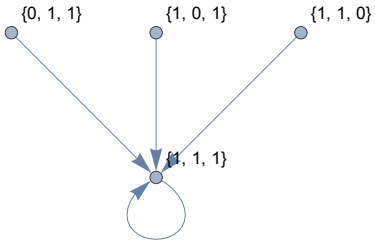
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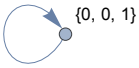
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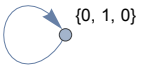
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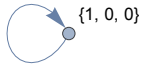
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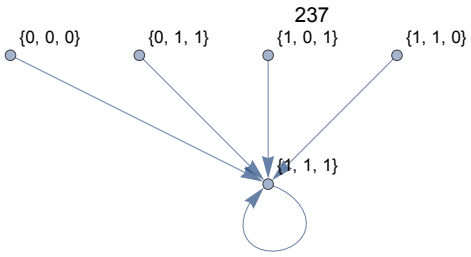
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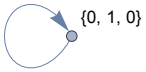
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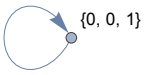
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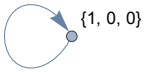
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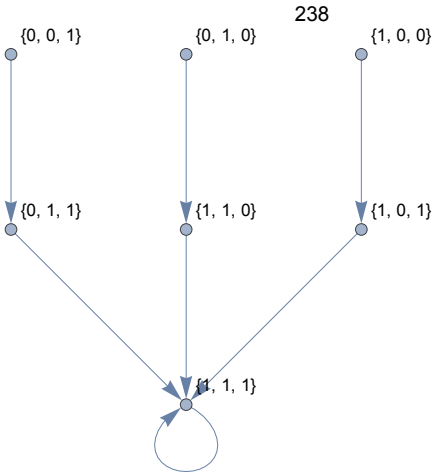
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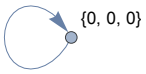
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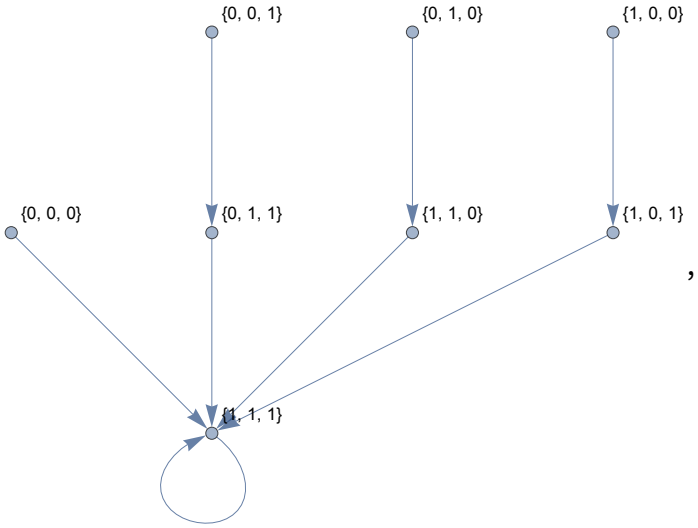

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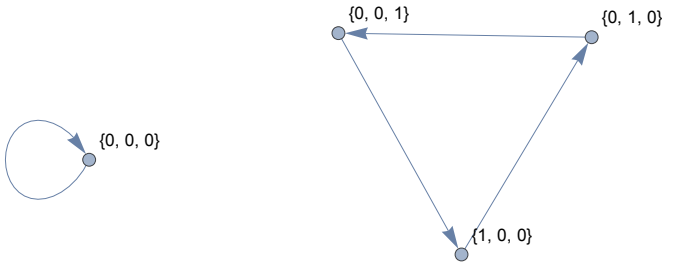

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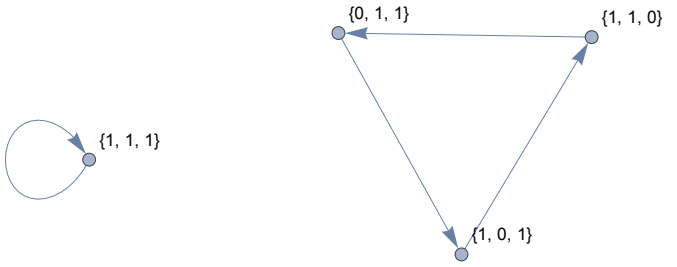

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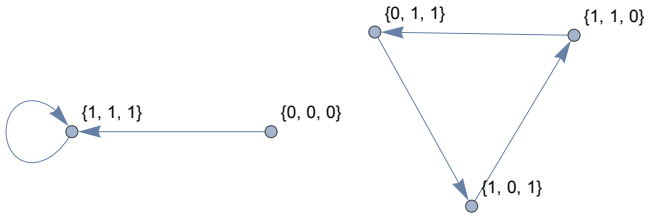

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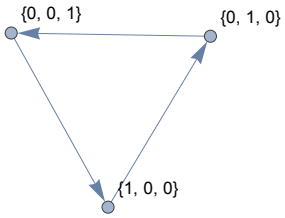

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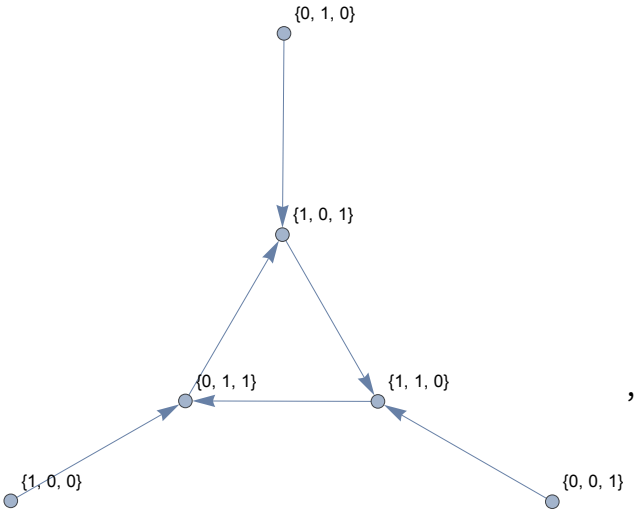

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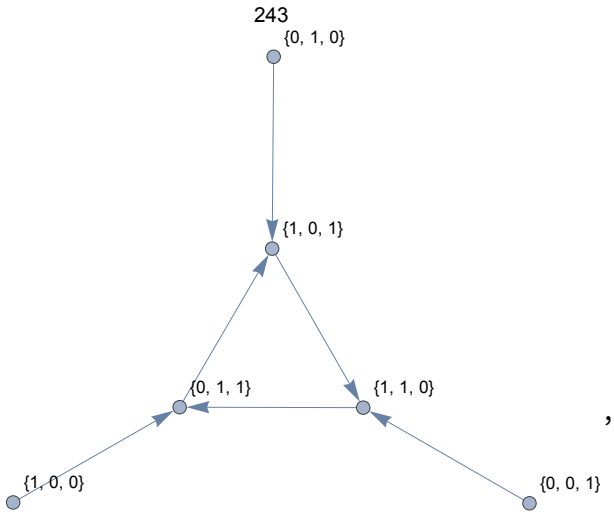
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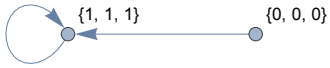
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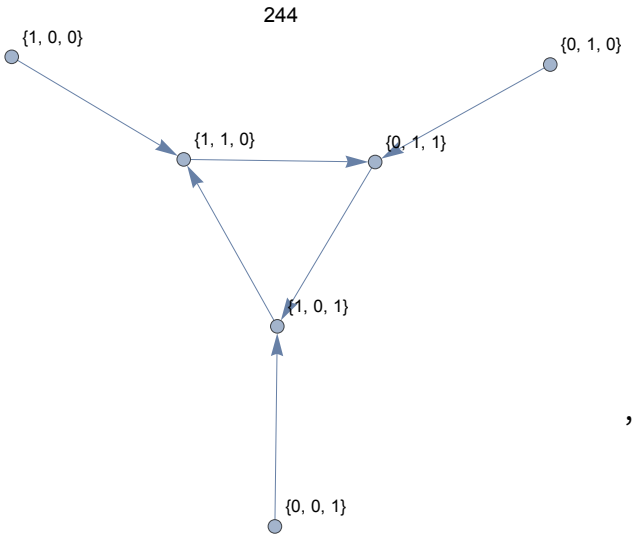
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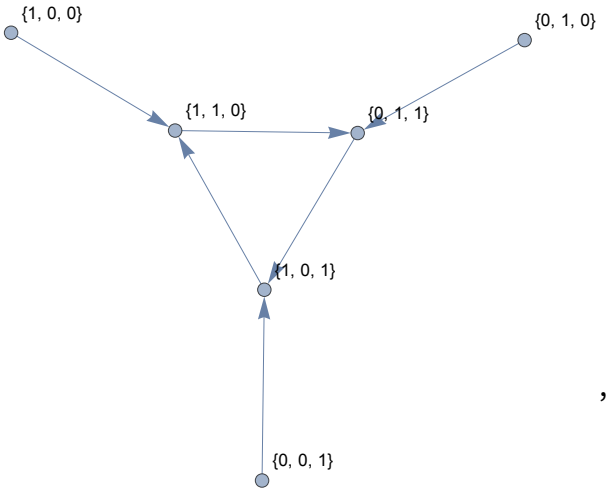

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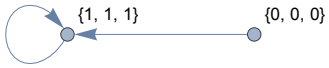

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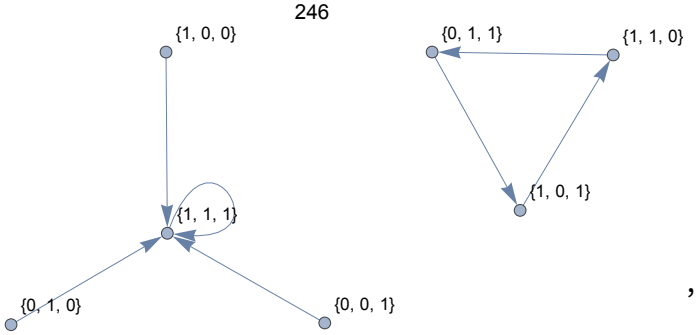

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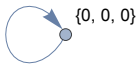

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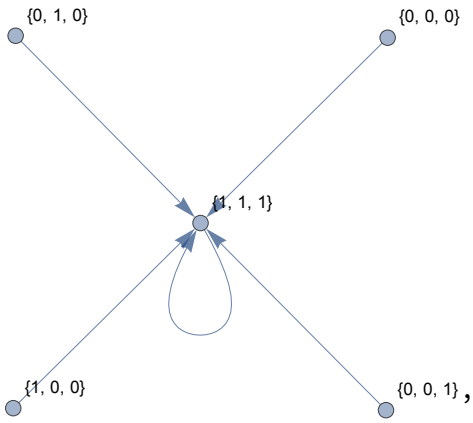

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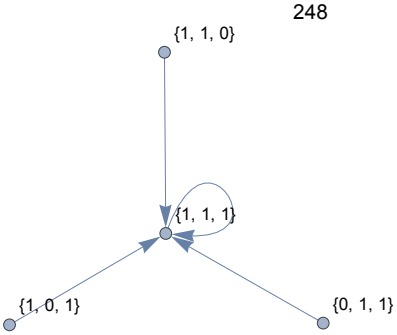

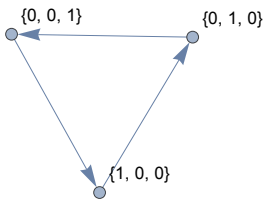

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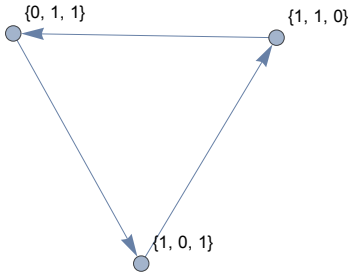

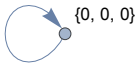

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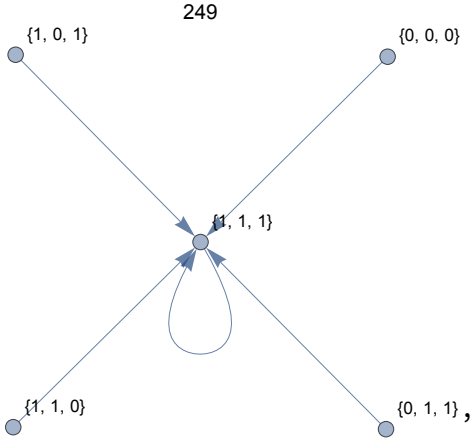
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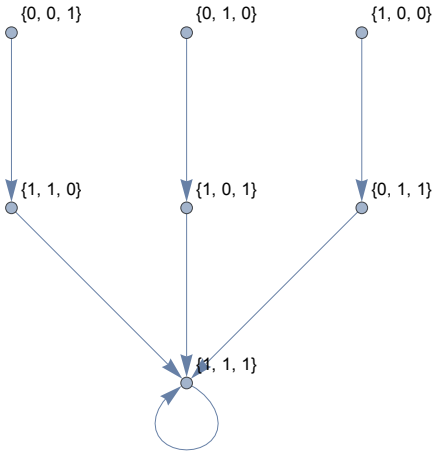
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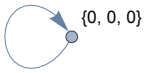
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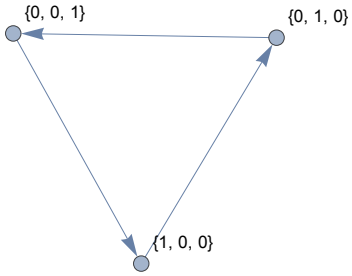
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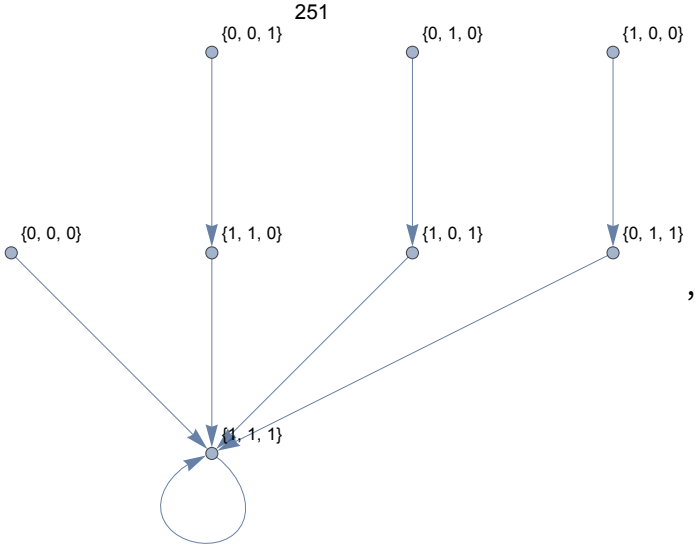
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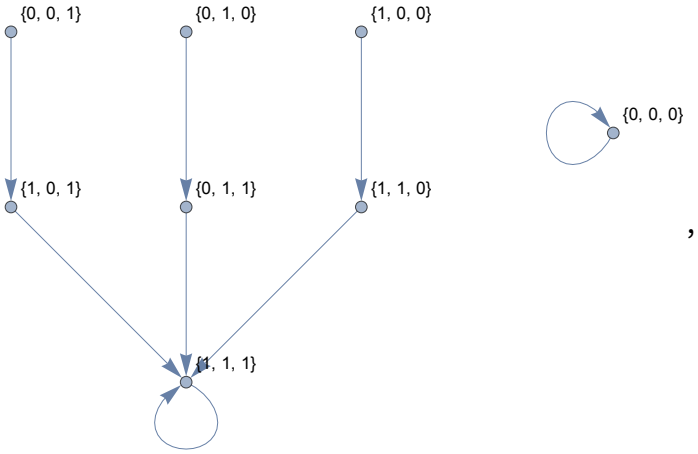

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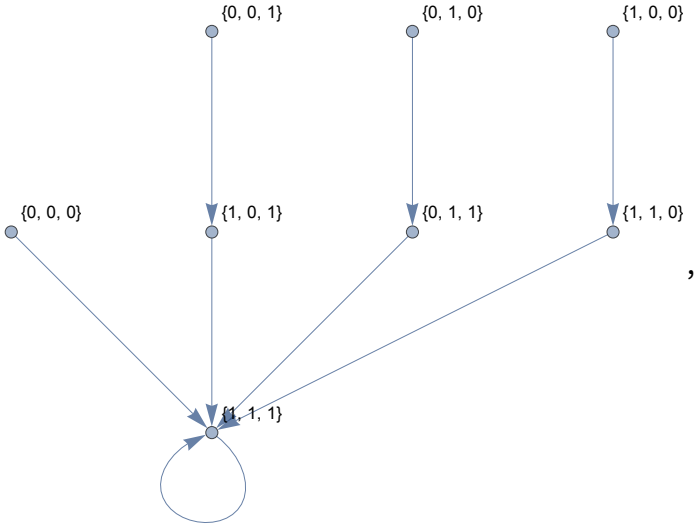

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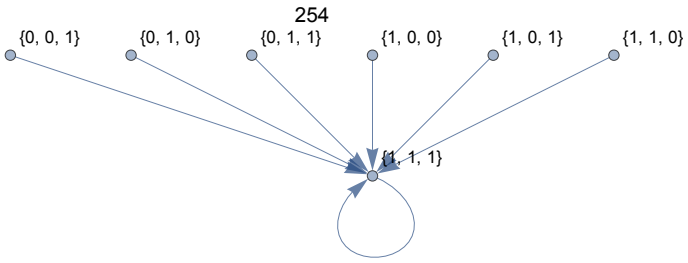
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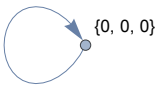
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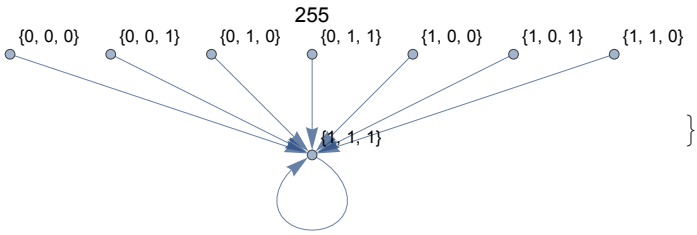
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Excellent!