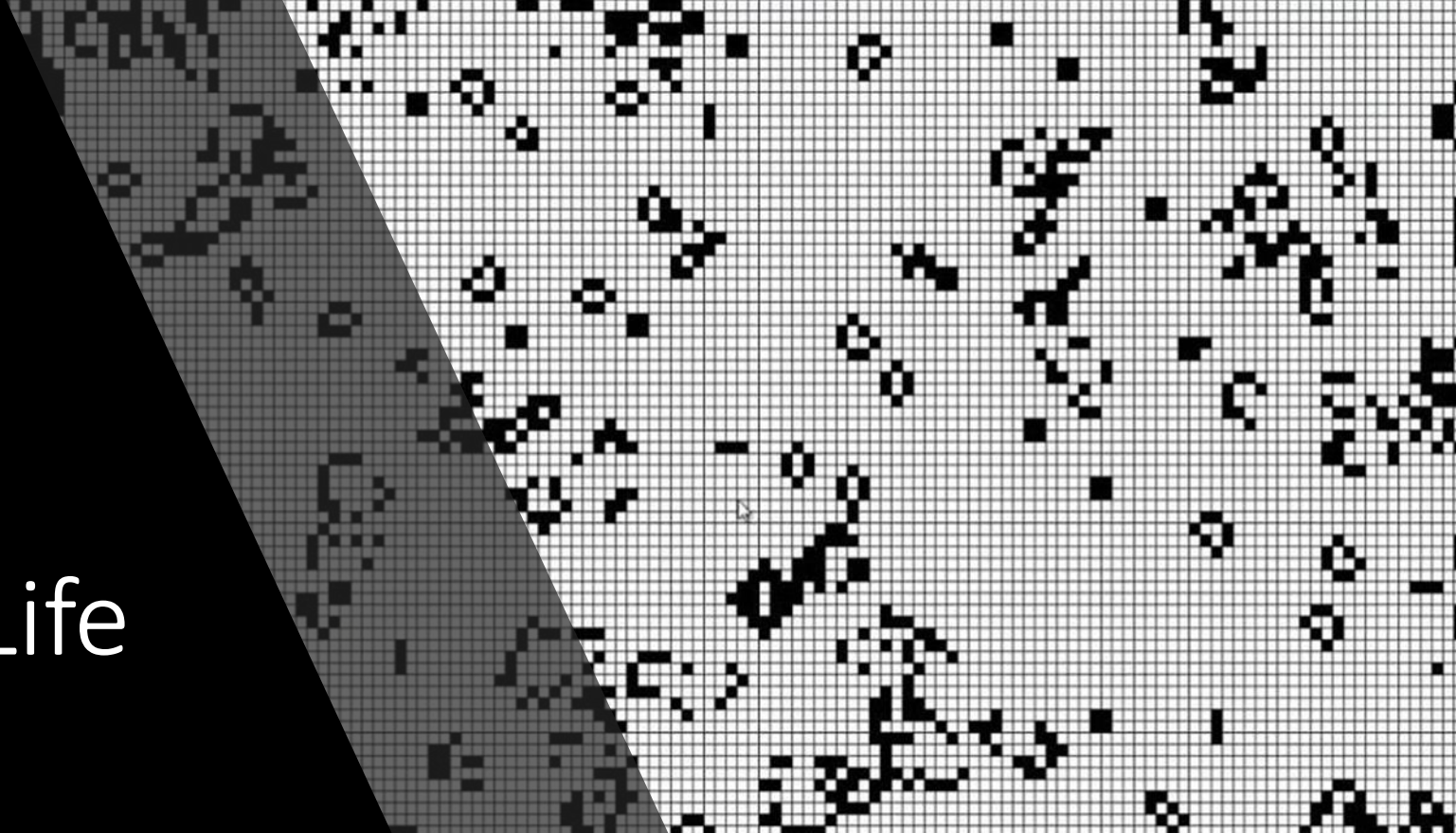


Coding with Neural Networks & Conway's Game of Life

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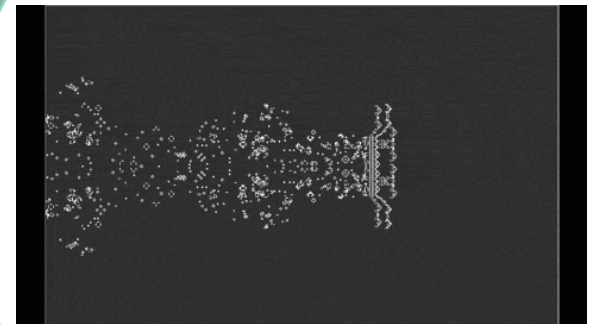
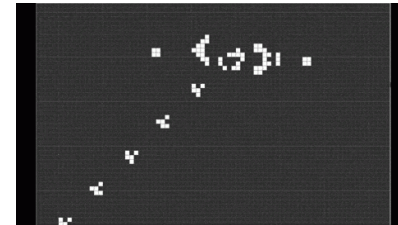
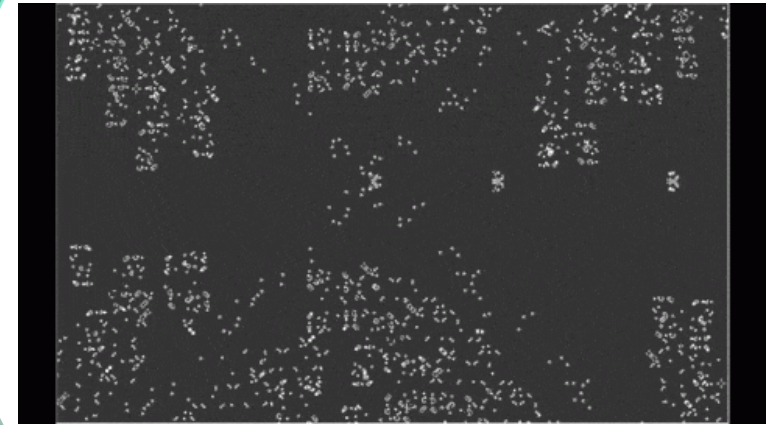
Where it all started....

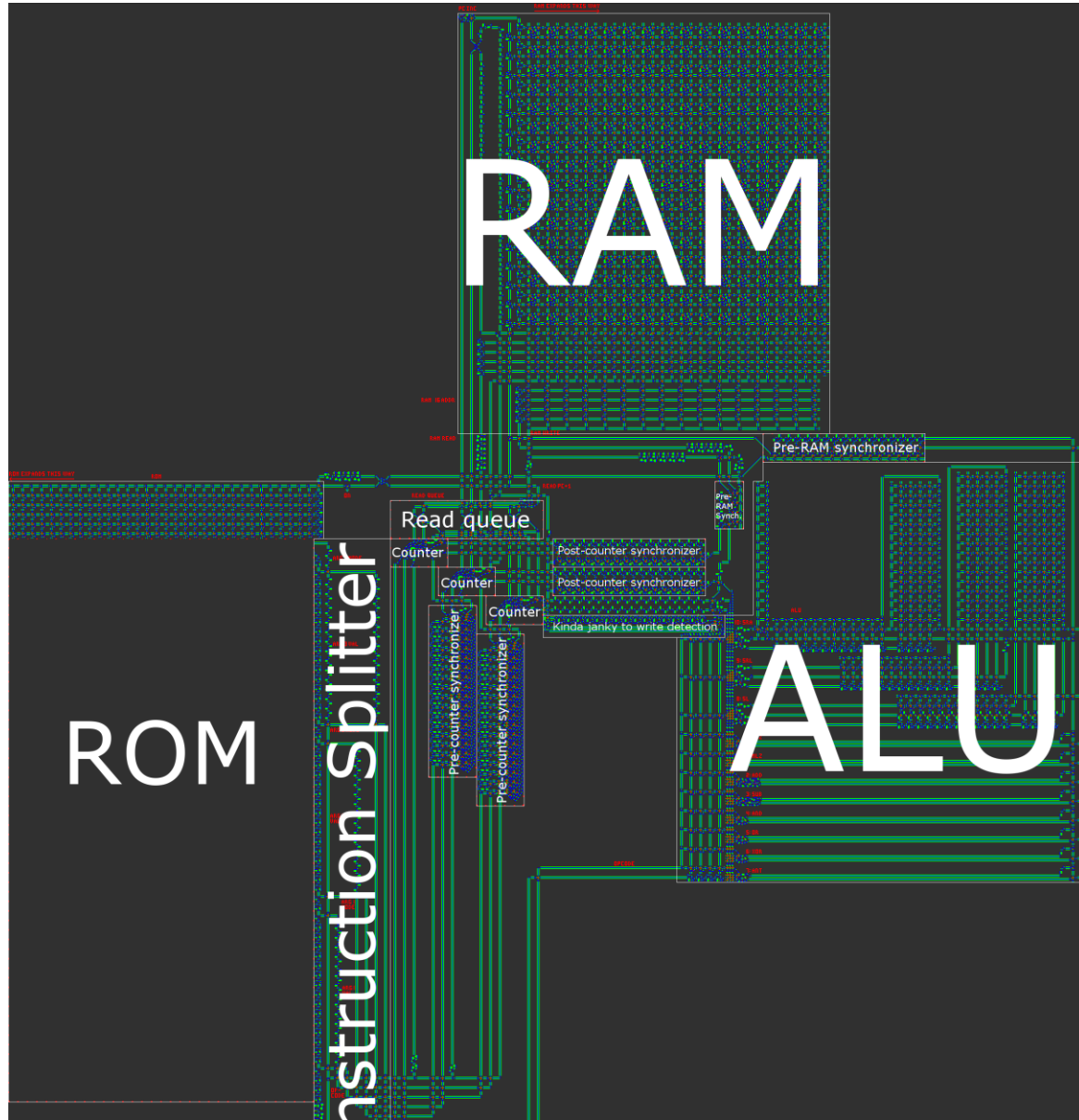
RNN Adventures

- Can an RNN learn Game of Life?
- Can an RNN simulate basic program structures (e.g. for loops)?

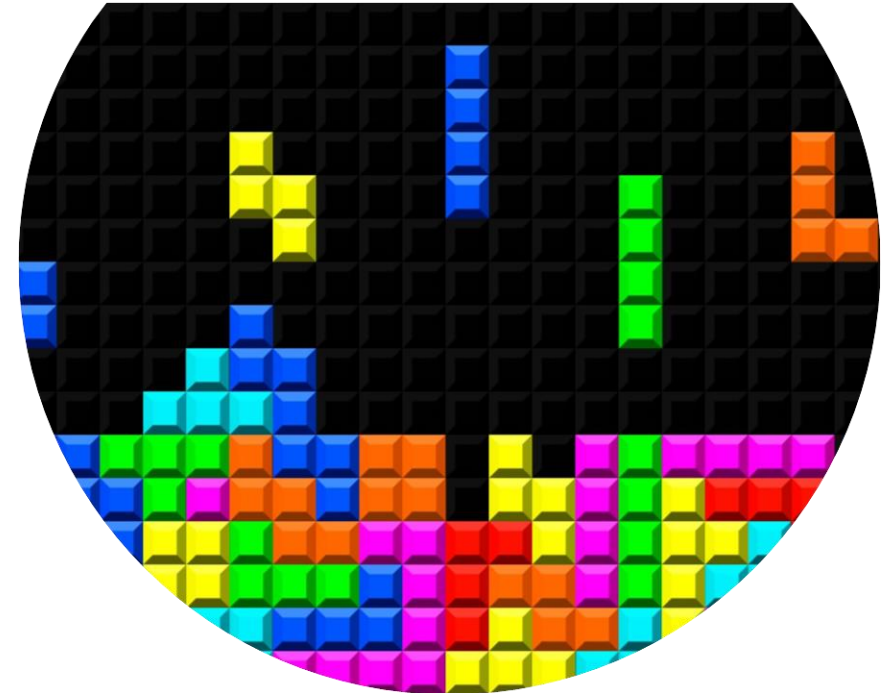
John Conway's Game of Life

- Rules:
- Each cell with one or no neighbors dies, as if by solitude.
- Each cell with four or more neighbors dies, as if by overpopulation.
- Each cell with two or three neighbors survives.
- Each cell with three neighbors becomes populated.

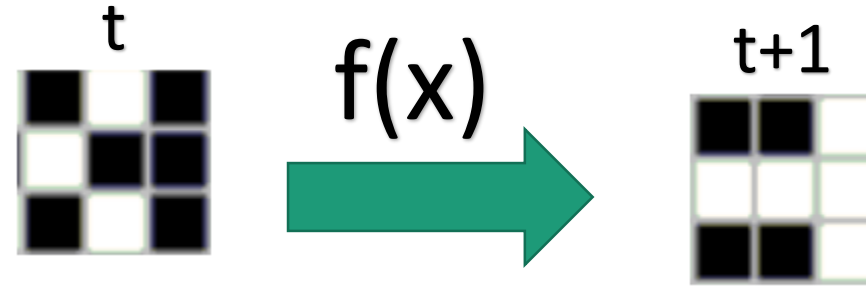




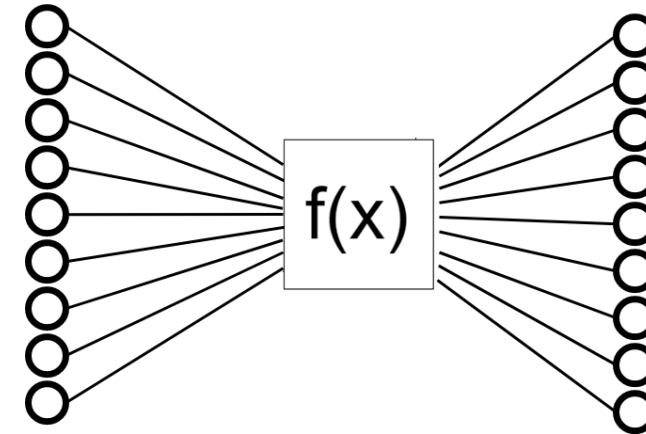
Game of Life is Turin
complete!



Game of Life Learning

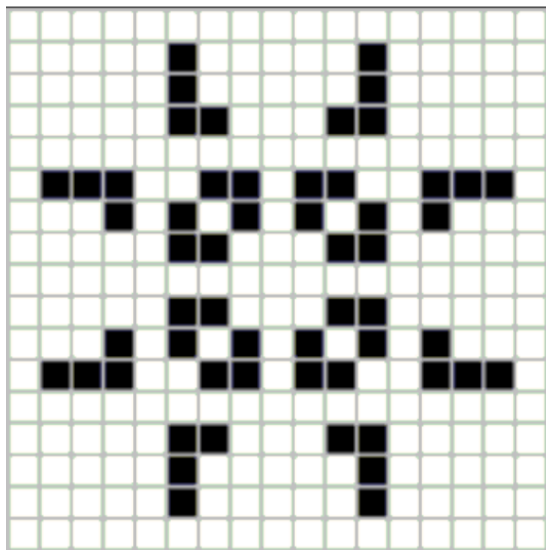


```
determinant_vas = input[:4] + input[5:]  
if sum(determinant_vas) < 2:  
    output[4] = 0.  
elif sum(determinant_vas) == 3:  
    output[4] = 1.  
elif sum(determinant_vas) > 3:  
    output[4] = 0.  
else:  
    output[4] = output[4]  
return output
```



Game of Life Learning

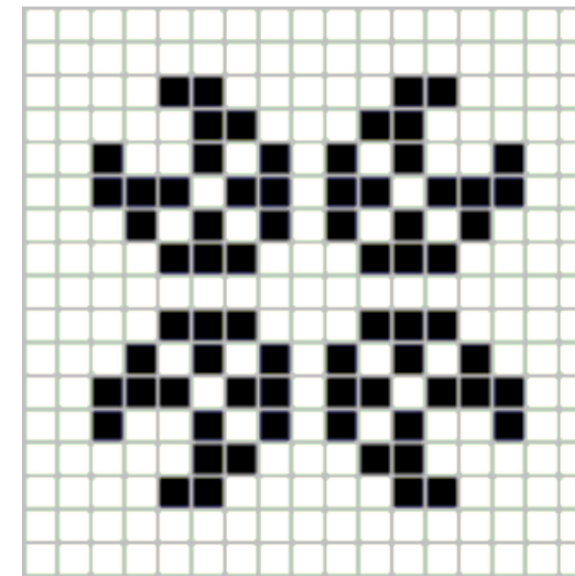
t



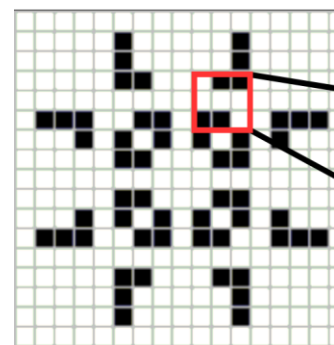
$f(x)$



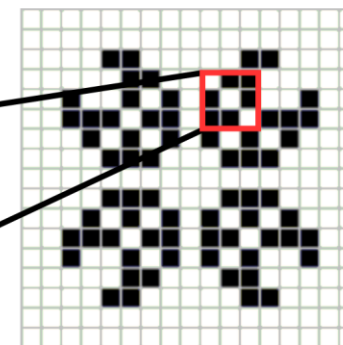
t+1



```
board = inputs[elem_idx, :].reshape(dim, -1)
next_board = copy.deepcopy(board)
for i in range(dim-2):
    for j in range(dim-2):
        board_patch = board[i+side_pad-1:i+side_pad+2,
                             j+side_pad-1:j+side_pad+2]
        predictions = self.gof_next_fun(board_patch.reshape(1, -1))
        next_board[i+side_pad, j+side_pad] = predictions[0, 4]
outputs[elem_idx, :] = next_board.reshape(1, -1)
```

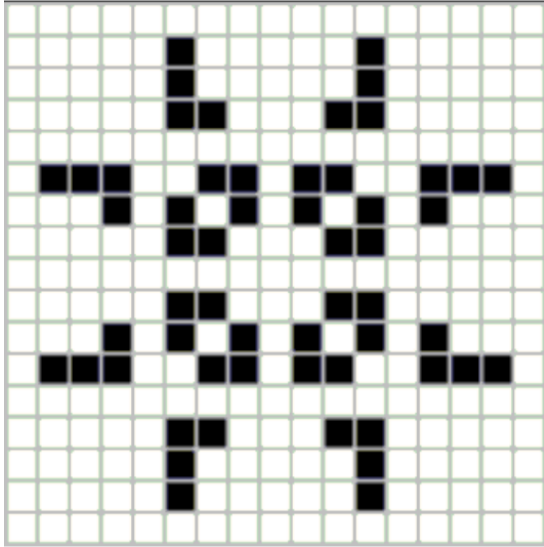


$f(x)$



Game of Life Learning

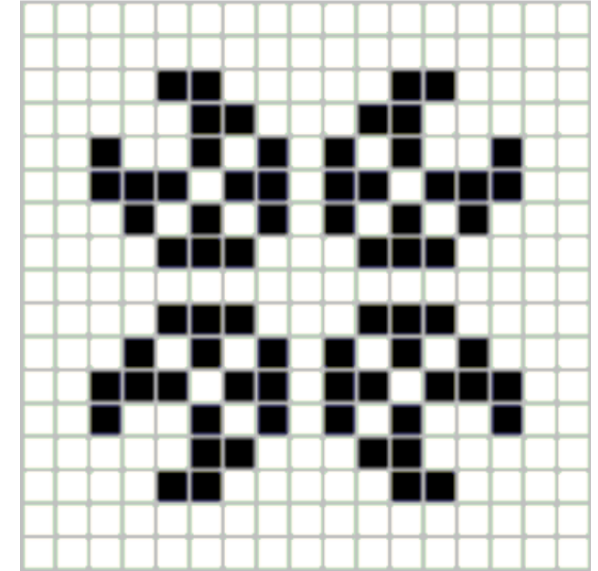
t



for i=0; i<n-1; n++:
do: f(x)



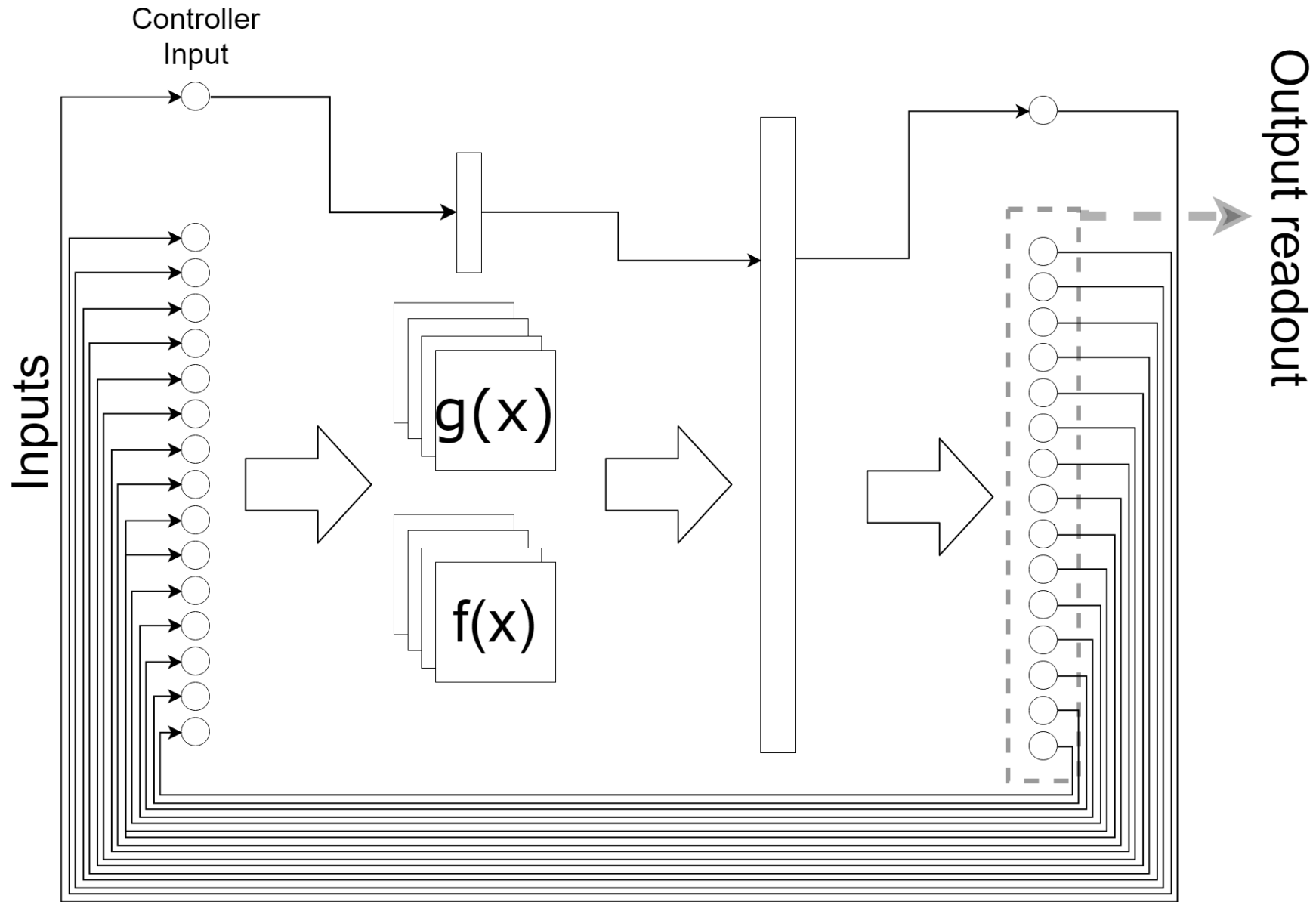
t+n



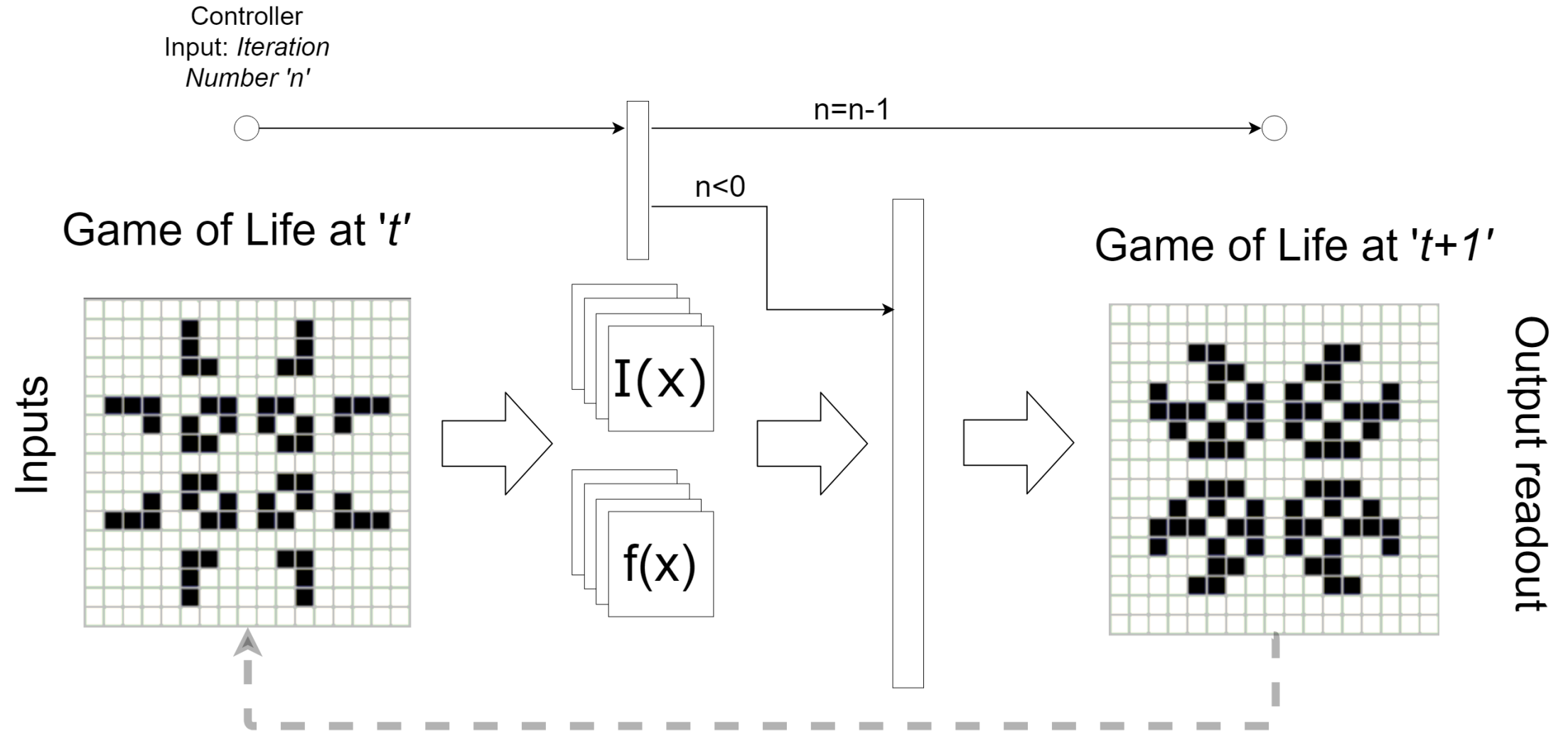
```
outputs = copy.deepcopy(inputs)
dim = np.sqrt(inputs.shape[1]).astype(np.int32)
for elem_idx in inputs.shape[0]:
    board = inputs[elem_idx, :].reshape(dim, -1)
    next_board = copy.deepcopy(board)
    for i in range(dim-2):
        for j in range(dim-2):
            board_patch = board[i+side_pad-1:i+side_pad+2,
                               j+side_pad-1:j+side_pad+2]
            predictions = self.gof_next_fun(board_patch.reshape(1, -1))
            next_board[i+side_pad, j+side_pad] = predictions[0, 4]
    outputs[elem_idx, :] = next_board.reshape(1, -1)
```

?

Modular Transfer Learning for Code Duplication



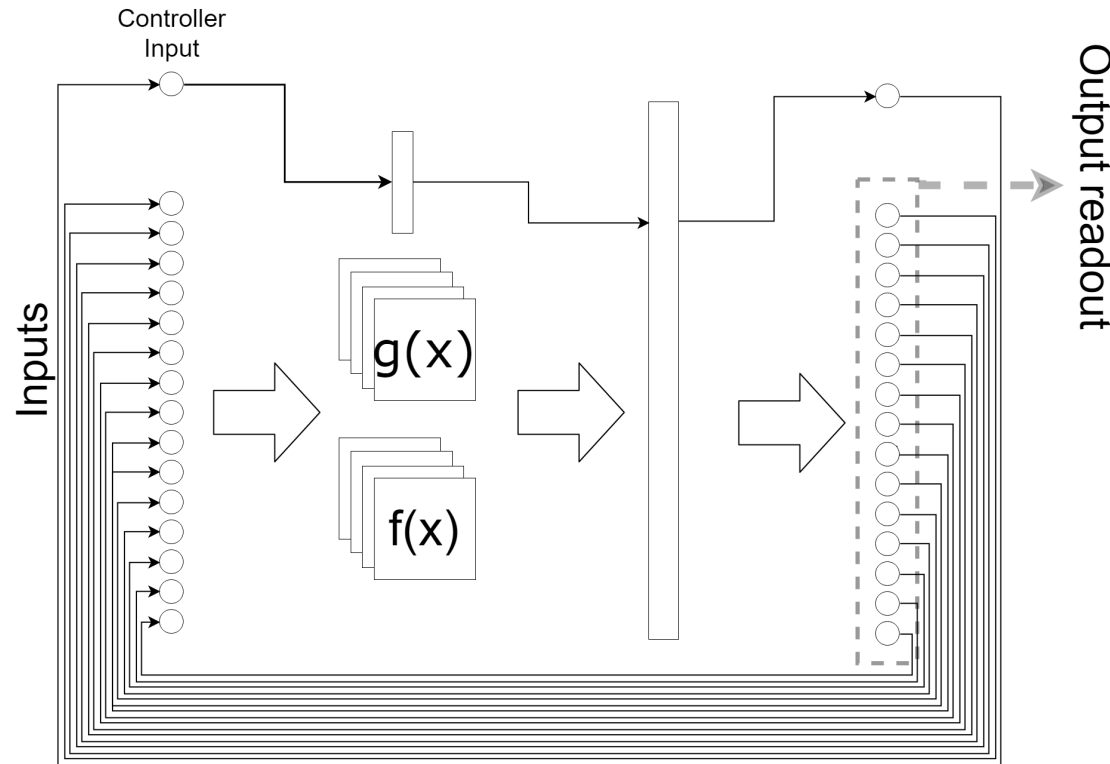
Modular Transfer Learning for Code duplication – Game of Life



Modular Transfer Learning for Code duplication

Pros

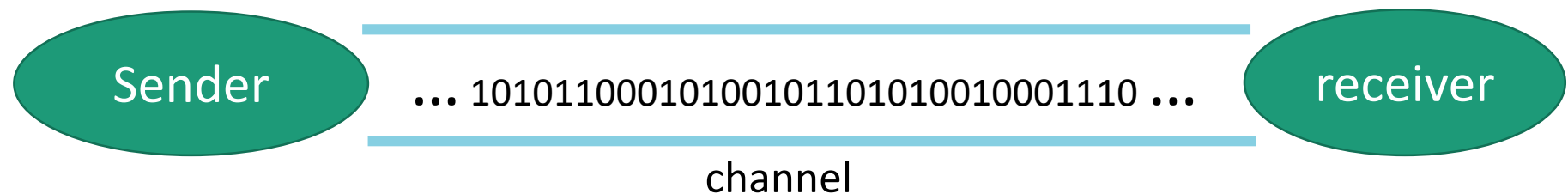
- Modularity
- Transparency
- Composability
- Unit-testable!
- Output-to-input -> akin to recursion!



Cons

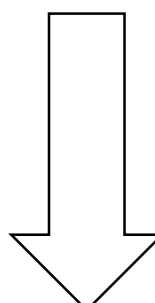
- Sparse training (though it can be automated)
- $f(x)$ can be arbitrary complex

More fun.... Parity bit checking



Parity bit

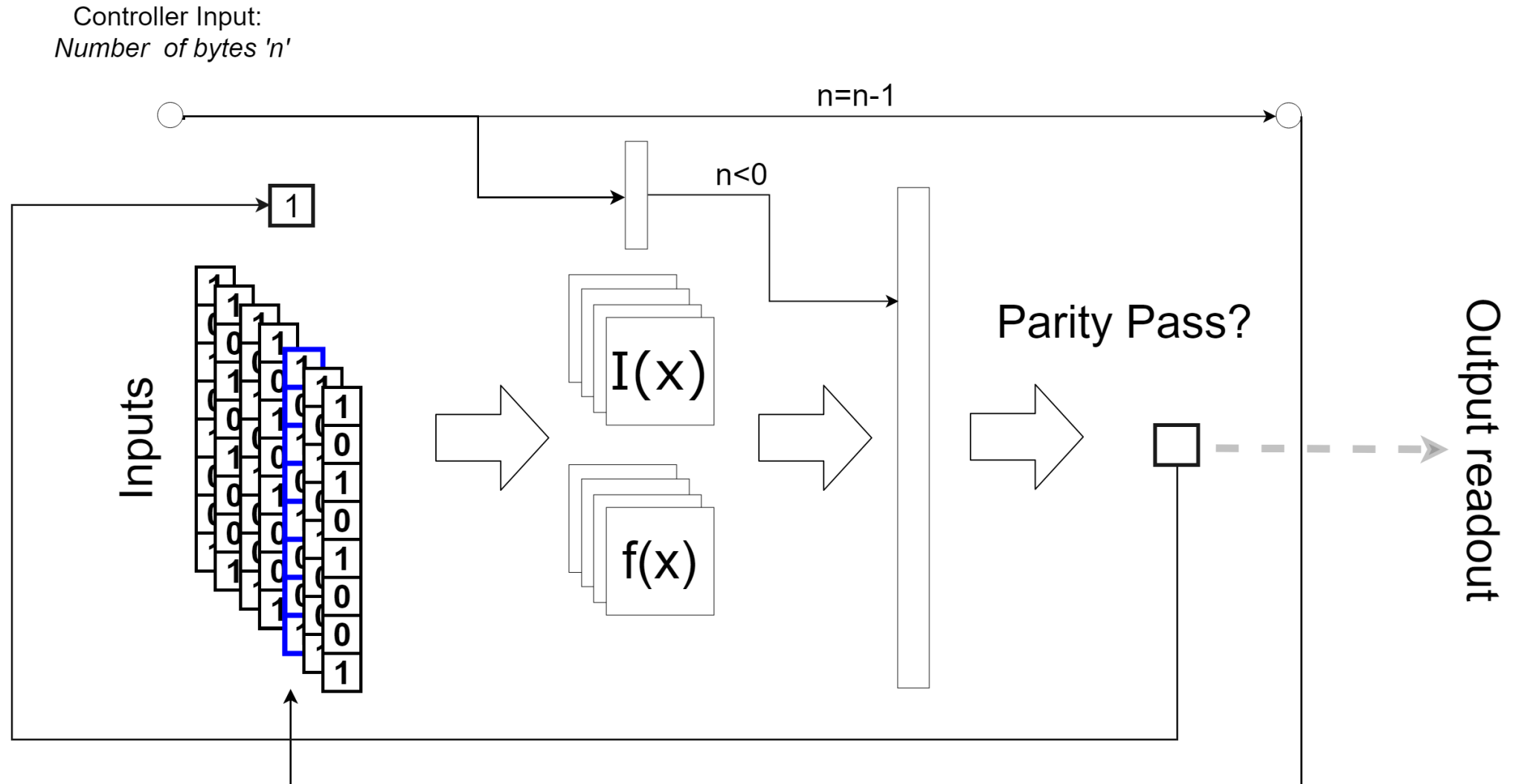
Information bits



byte 1	1	1	1	1	0	1	1	0
byte 2	1	0	0	1	0	1	0	1
byte 3	0	1	1	1	1	1	1	0
byte 4	1	0	0	0	0	0	1	0
byte 5	0	1	1	0	1	0	0	1
byte 6	1	0	0	0	1	0	0	0
byte 7	1	0	1	0	1	1	1	1
byte 8	0	0	0	1	1	0	1	0
byte 9	0	0	0	1	0	0	1	0

The table displays 9 bytes of data. Each byte is represented by 9 bits. The first bit of each byte is the Parity bit, and the remaining 8 bits are the Information bits. The Parity bit for byte 1 is highlighted with a red box.

Modular Transfer Learning for Code duplication – Parity Bit Checking



Some repercussions of this...

- **Depth in NN is overrated!**

Selective training can obviate (some) of the need for depth! i.e. some seemingly large or infinite problems can be solved trivially with appropriate (shallow) architectures)

- **There may be a future where we do not need Software Engineers anymore (just network designers)**

Composability allows for autonomous network design and generation (i.e. it has the potential to automate the architecture generation for any given program.)s

- **Solving the training sample generation problem could lead to software which automatically conforms to ever changing software requirements!**

(no need for agile programming anymore!)

Thank you!

Luca Scimeca &
Andrzej Banburski

```
154  
155 function updatePhotoDescription() {  
156   if (descriptions.length > (page * 9) + (currentImage.substring(3, 4)) {  
157     document.getElementById('bigImageDesc').innerHTML = descriptions[(page * 9) + currentImage.substring(3, 4)]  
158   }  
159 }  
  
function updateAllImages() {  
  var i = 1;  
  while (i < 10) {  
    var elementId = 'foto' + i;  
    var elementIdBig = 'bigImage' + i;  
    if (page * 9 + i - 1 < photos.length) {  
      document.getElementById(elementId).src = 'images/min/' + photos[(page * 9) + i - 1] + '.jpg';  
      document.getElementById(elementIdBig).src = 'images/max/' + photos[(page * 9) + i - 1] + '.jpg';  
    }  
    i++;  
  }  
}
```