LE

December 3, 2025

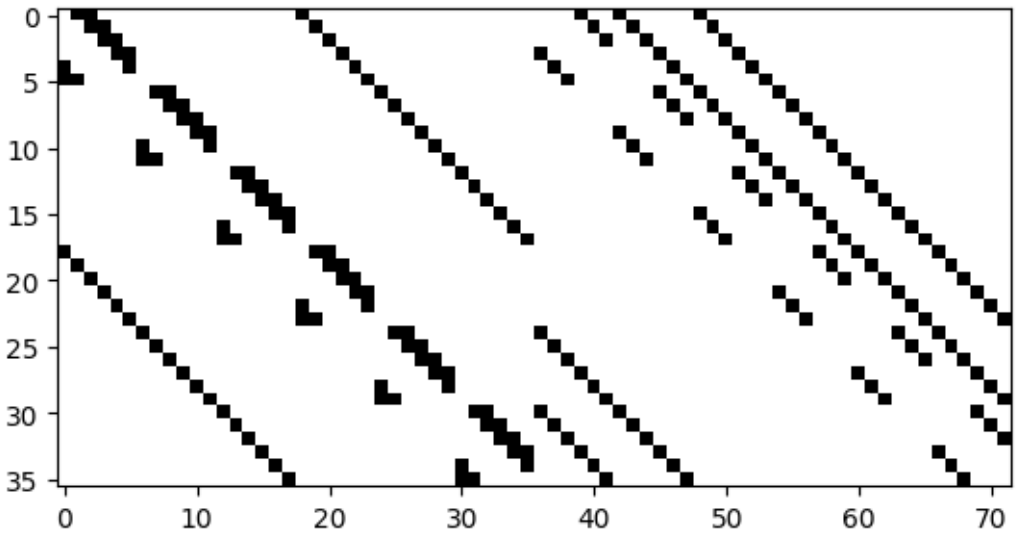
[49]:
```
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.colors import ListedColormap
```

[50]:
```
from beliefPropagation import performBeliefPropagation
```

[51]:
```
code = "[[72, 12, 6]]"

matrix = np.load(f"codes/{code}.npz")
n = 72
k = 12
```

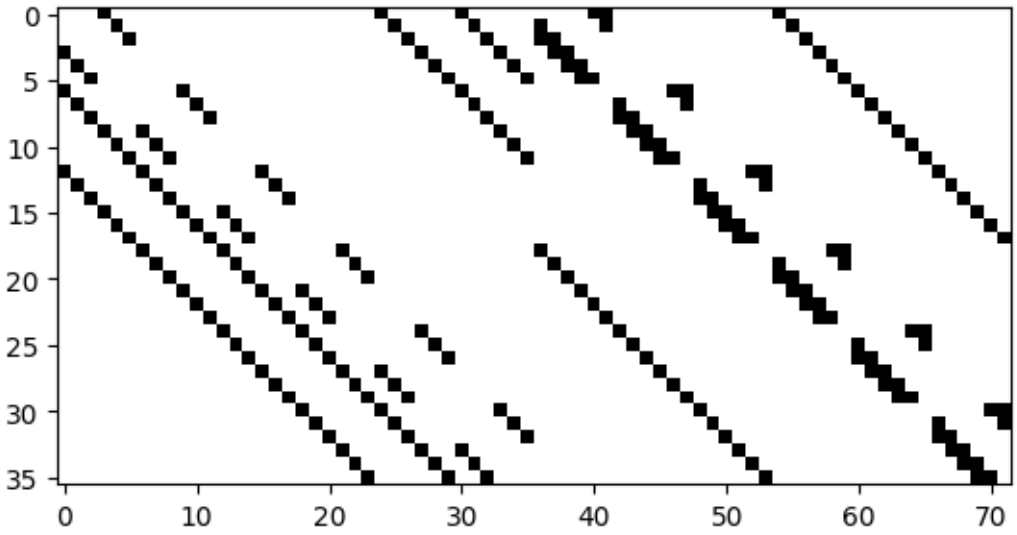
[52]:
```
Hx = matrix["Hx"]
plt.imshow(Hx, cmap='Greys', interpolation='nearest')
```

[52]:
```
<matplotlib.image.AxesImage at 0x11a3e23c0>
```



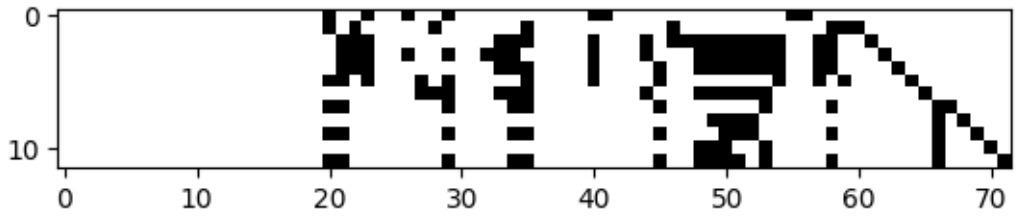
[53]:
```
Hz = matrix['Hz']
plt.imshow(Hz, cmap="Greys", interpolation="nearest")
```

[53]: <matplotlib.image.AxesImage at 0x119e868a0>



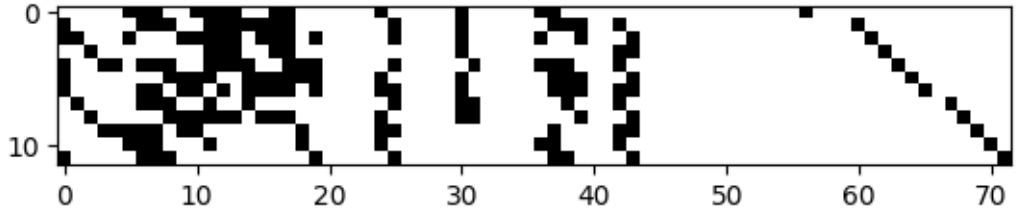
[54]:
```
Lx = matrix['Lx']
plt.imshow(Lx, cmap="Greys", interpolation="nearest")
```

[54]: <matplotlib.image.AxesImage at 0x12688aae0>



[55]:
```
Lz = matrix['Lz']
plt.imshow(Lz, cmap="Greys", interpolation="nearest")
```

[55]: <matplotlib.image.AxesImage at 0x126a170e0>



[56]:
```
print(Hx.shape)
print(Lx.shape)
```

```
(36, 72)
(12, 72)
```

[79]:
```
# logical operator anticommute
np.sum((Hz @ Lx.T) % 2 )
```

[79]:
```
np.int64(0)
```

[80]:
```
np.sum((Hx @ Lz.T) % 2)
```

[80]:
```
np.int64(0)
```

[57]:
```
errorRate = 0.05
```

[58]:
```
# set numpy random seed
np.random.seed(0)
```

[59]:
```
error = (np.random.rand(n) < errorRate).astype(int)
print(error)

# trivial error
error = Hz[0].copy()
```

```
[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
```

[60]:
```
# e_actual != e_decoded
# but
# e_actual + e_decoded \in S
e_simple = np.zeros(n, dtype=int)
e_simple[0] = 1

stabilizer = Hz[0].copy()
e_actual = (e_simple + stabilizer) % 2
error = e_actual.copy()
```

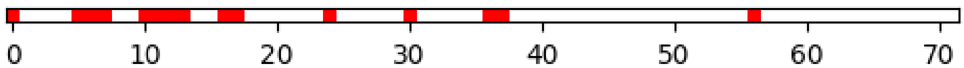
[61]:
```
# non-trivial error
e_simple = np.zeros(n, dtype=int)
e_simple[0] = 1

logical_op = Lz[0].copy()
e_actual = (e_simple + logical_op) % 2
error = e_actual.copy()
```

```
[62]: print(error.reshape(1, -1)) # this is just for plt, since it wants a matrix
```

```
[[1 0 0 0 0 1 1 1 0 0 1 1 1 1 0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0
  1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]]
```

```
[63]: cmap = ListedColormap(['white', 'red'])
plt.imshow(error.reshape(1, -1), cmap=cmap, interpolation="nearest")
plt.yticks([])
```

```
[63]: ([], [])
```




```
[64]: initialBeliefs = [np.log((1 - errorRate) / errorRate)] * n
print(initialBeliefs)
```

```
[np.float64(2.9444389791664403), np.float64(2.9444389791664403),
np.float64(2.9444389791664403), np.float64(2.9444389791664403),
np.float64(2.9444389791664403), np.float64(2.9444389791664403),
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np.float64(2.9444389791664403), np.float64(2.9444389791664403),
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np.float64(2.9444389791664403), np.float64(2.9444389791664403),
np.float64(2.9444389791664403), np.float64(2.9444389791664403),
np.float64(2.9444389791664403), np.float64(2.9444389791664403),
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np.float64(2.9444389791664403), np.float64(2.9444389791664403),
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np.float64(2.9444389791664403), np.float64(2.9444389791664403),
np.float64(2.9444389791664403), np.float64(2.9444389791664403)]
```

[65]:
```
plt.imshow(np.asarray(initialBeliefs).reshape(1, -1), interpolation='nearest')
plt.yticks([])
```

[65]: ([], [])

[66]:
```
detection, isSyndromeFound, lastBeliefs = performBeliefPropagation(Hx, error,␣
↪initialBeliefs)
```

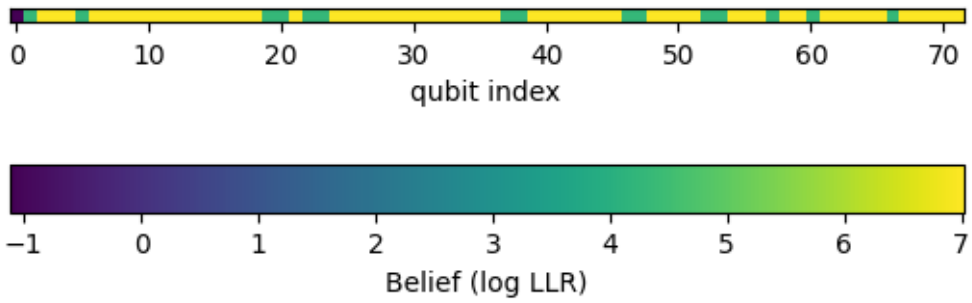
```
Initial syndrome: [0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.
0. 0. 0. 0.
 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
Error found at iteration 0: [1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
```

[67]:
```
print(detection, isSyndromeFound)
```

```
[1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0] True
```

[68]:
```
im = plt.imshow(np.asarray(lastBeliefs).reshape(1, -1), interpolation='nearest')
cbar = plt.colorbar(im, orientation='horizontal', pad=0.2)
cbar.set_label('Belief (log LLR)')
plt.xlabel('qubit index')
plt.yticks([])
```

[68]: ([], [])



[69]:
```
residual = (detection + error) % 2
print(residual)
```

```
[0 0 0 0 0 1 1 1 0 0 1 1 1 1 0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 1
 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
```

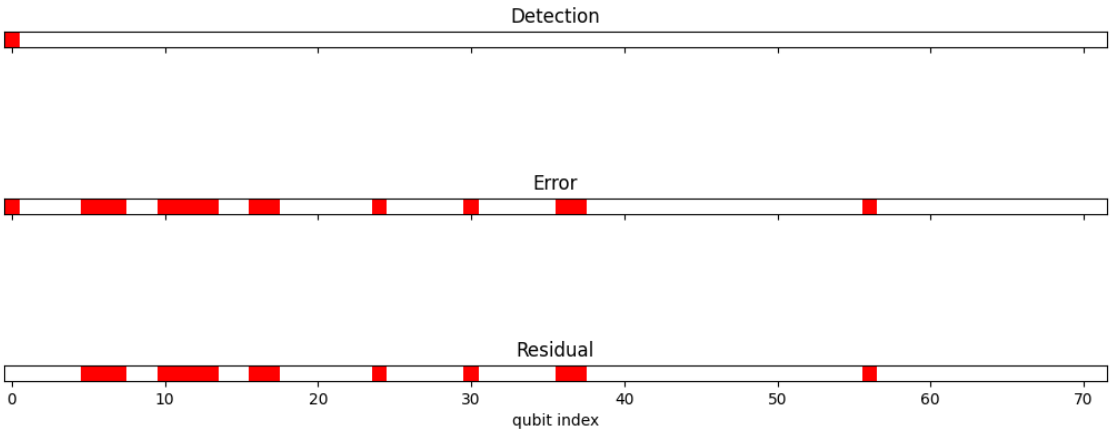
[70]:
```
fig, axs = plt.subplots(3, 1, figsize=(10, 4.5), sharex=True,␣
 ↪constrained_layout=True)

axs[0].imshow(detection.reshape(1, -1), cmap=cmap, interpolation="nearest")
axs[0].set_yticks([])
axs[0].set_title("Detection")

axs[1].imshow(error.reshape(1, -1), cmap=cmap, interpolation="nearest")
axs[1].set_yticks([])
axs[1].set_title("Error")

axs[2].imshow(residual.reshape(1, -1), cmap=cmap, interpolation="nearest")
axs[2].set_yticks([])
axs[2].set_title("Residual")
axs[2].set_xlabel("qubit index")
```

[70]:
```
Text(0.5, 0, 'qubit index')
```

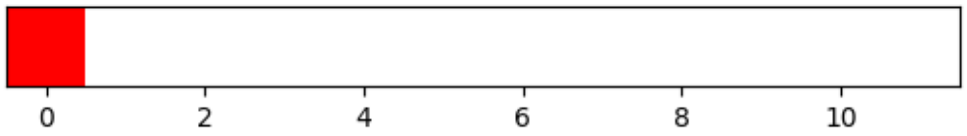


[71]:
```
# Lx is a 12 x 72 matrix, and residual is a 1 x 72 vector
print(Lx.shape, residual.shape)
syndromeLogicError = (Lx @ residual) % 2 # we do not need the transpose since @␣
↪does the broadcasting. I think is considered as a trivial case
print(syndromeLogicError)
```

```
(12, 72) (72,)
[1 0 0 0 0 0 0 0 0 0 0 0]
```

[72]:
```
plt.imshow(syndromeLogicError.reshape(1, -1), cmap=cmap,␣
↪interpolation="nearest")
plt.yticks([])
```

[72]:
```
([], [])
```



[ ]:
```

```