Classification of Digits

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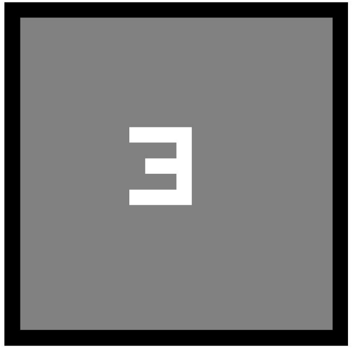
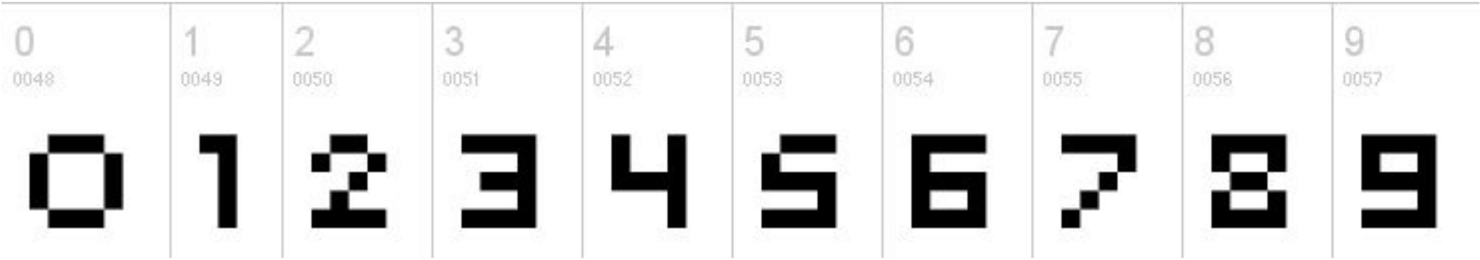
Goals

- Develop classifier for digits set in a 5x5 frame
- Systematically remove information from assumptions





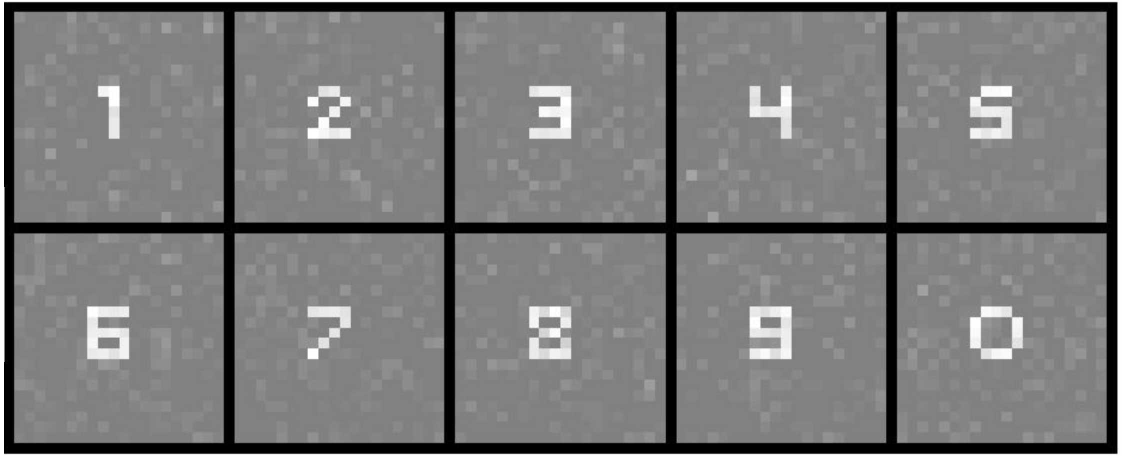
Digits in noise

- Color is grayscale (0,255)
- Ideal digit color is 127
- Becomes a Minimum distance receiver.
- Choose Hi for which:

$$T_i(x) = \sum_{n=1}^{N} x[n]s_i[n] - \frac{1}{2}\epsilon_i$$

is maximum

- Pe = 0



Digits in noise, unknown location

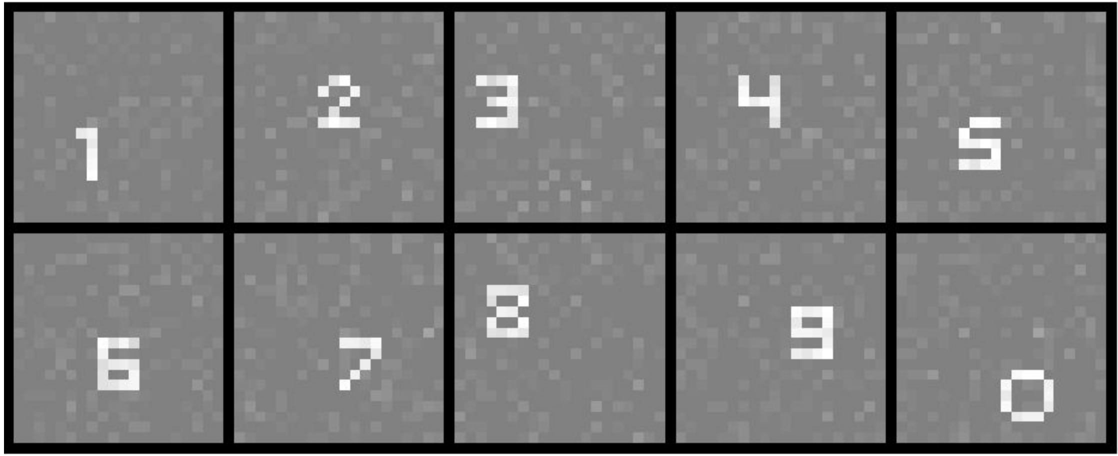
- Becomes minimum distance receiver with unknown arrival time in 2 dimensions
- decide Hi for which:

$$T_i(x) = \max_{n_0, m_0 \in 1,16} \sum_{n=n_0, m=m_0}^{n=N-1, m=M-1} x[n] s_i[n,m] - \frac{\epsilon_i}{2}$$

$$N, M = 20$$

is maximized

- Pe = .0132
- 66 out of 5000



Unknown size

- unknown size is not the same as amplitude because the signal changes.
- same detector as before but optimized over a different parameter
- choose Hi for which:

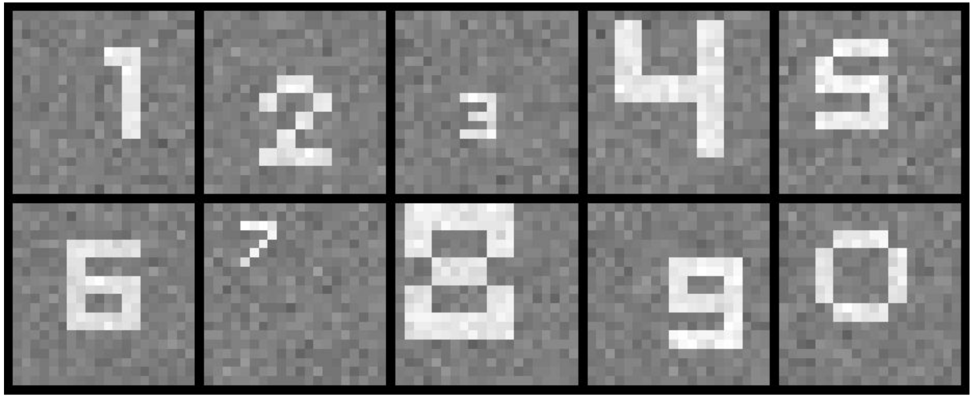
$$T_i(x) = \max_{s \in 1,3} \sum_{n=0}^{N-1} x[n] s_i[n, s] - \frac{\epsilon_i}{2}$$

is maximum

- Pe = 0
- Errors are small because we sometimes are increasing the energy to noise ratio of the signal

Unknown size and location

- Again a minimum distance receiver optimized over the unknown parameters
- Pe = .0022
- 11 out of 5000



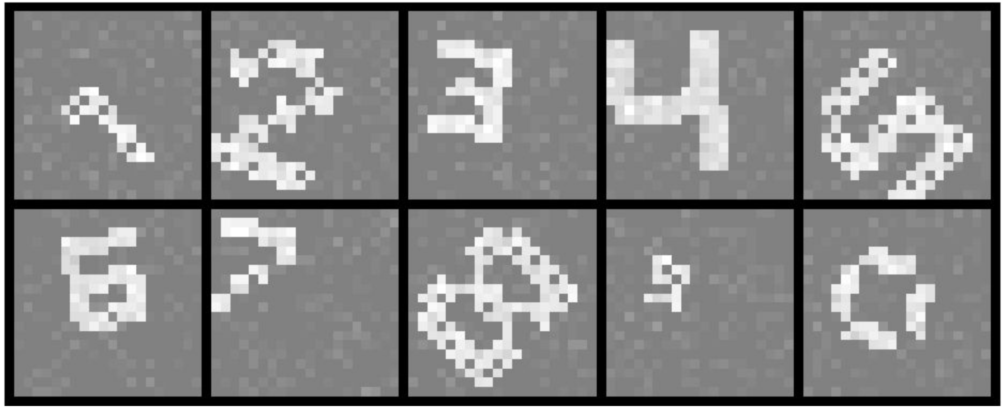
Unknown size, location, rotation

- As before a minimum distance receiver optimized over unknown parameters
- choose Hi for which:

$$T_i(x) = \max_{n_0,m_0 \in 1,16 \;\; s \in 1,3 \;\; r \in -\frac{\pi}{4},\frac{\pi}{4}} \sum_{n=n_0,m=m_0}^{n=N-1,m=M-1} x[n] s_i[n,m,s,r] - \frac{\epsilon_{i,s,r}}{2}$$

$$N, M = 20$$

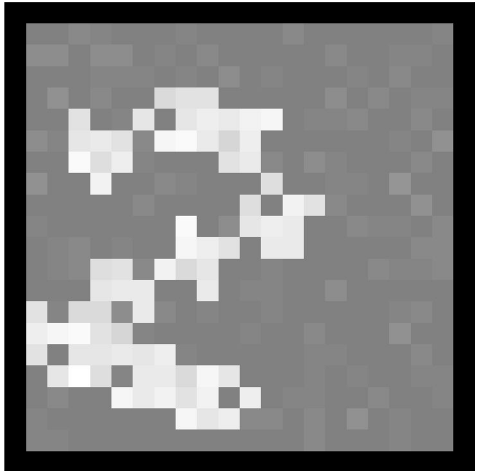
is maximum.

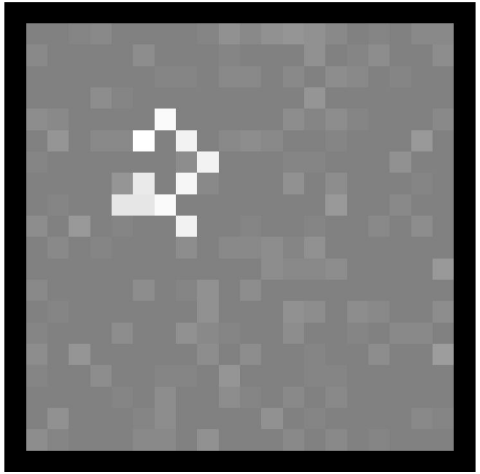


- Pe = .0076
- 38 out of 5000

Note on translation, scaling, and rotation processes

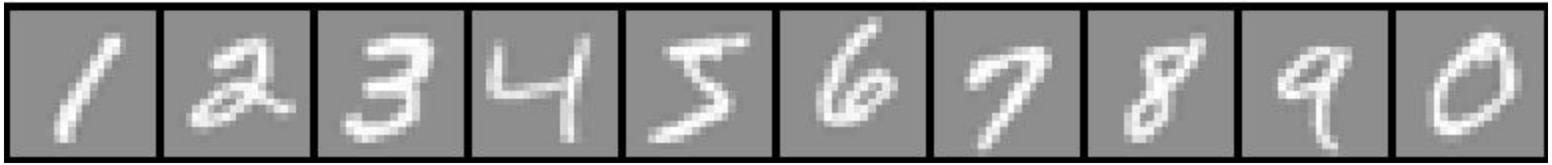
- Do not take into account interpolation
- Some rotations will come out better than others
- Using the same functions to generate the data and then detect makes the error very low.





Written digits

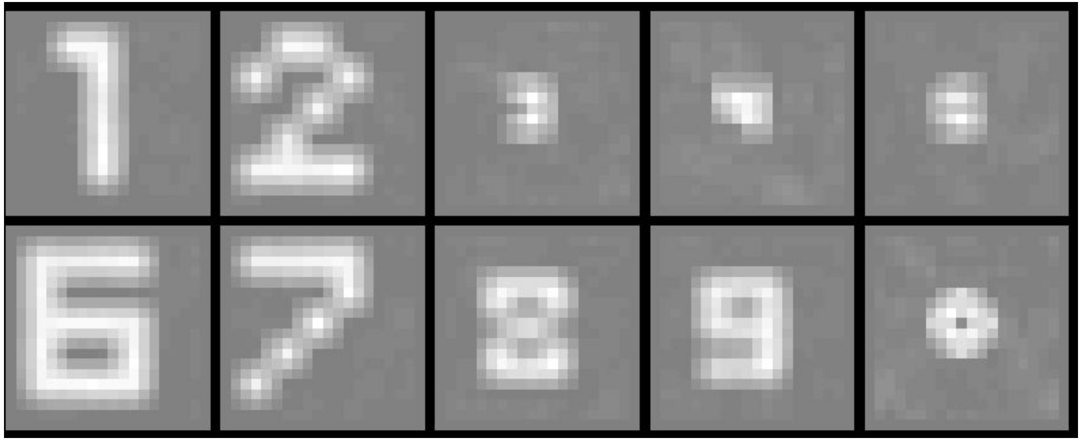
- Low error isn’t really that accurate
- The problems weren’t really different
- Use the same detector from previous slide on a different data set.
- Pe = .6884
- Pretty good compared to random classifier.



Written digits cont.

- Notice that written digits have smoother edges.
- blur the templates to make them closer the written digits.

- Simple 3x3 pixel averager



Written digits cont.

- After using the detector with blurred templates.
- Pe = .5174
- much better than random classification
- even pretty good compared to previous Pe = .6884

digit	1	2	3	4	5	6	7	8	9	0
1	492	4	0	0	0	0	3	0	1	0
2	79	207	68	40	5	2	43	24	7	25
3	101	33	160	8	70	2	37	14	20	55
4	8	19	5	353	17	18	22	19	19	20
5	14	23	27	19	252	16	53	9	15	72
6	8	25	8	23	118	227	1	11	41	38
7	143	11	9	3	2	1	313	6	3	9
8	149	62	41	22	89	25	11	48	39	14
9	70	4	13	111	32	15	94	8	110	43
0	1	4	41	2	4	92	26	22	57	251

Written digits cont.

- I think that I could improve the performance even more if I fixed the translation, scaling, and rotation processes to include interpolation.
- Maybe added a shrinker/stretcher process to account for slender digits like ‘8’.
- Obviously working with higher resolution images would help
- At that point the calculations would take prohibitively long.
    - a relatively small data set of 5000 images took about 1 hour to do the calculations on