Digits Recognizer

Group 2
G.X. Liu, D.W. Chen and K.I. Chung

June 21, 2017

https://goo.gl/Ac1aXg

The Handwritten Digits

They are originally from the MNIST database.

- 60000 training data
- 10000 test data

Now, it is a competition on the Kaggle.

- 42000 training data
- 28000 test data

Information

- Images contain 28×28 pixels.
- There are 784 independent variables.
- The response labels the real values of images.

Table: Frequency of Digits

digit	0	1	2	3	4
freq.	4132	4684	4177	4351	4072
digit	5	6	7	8	9
freq.	3795	4137	4401	4063	4188

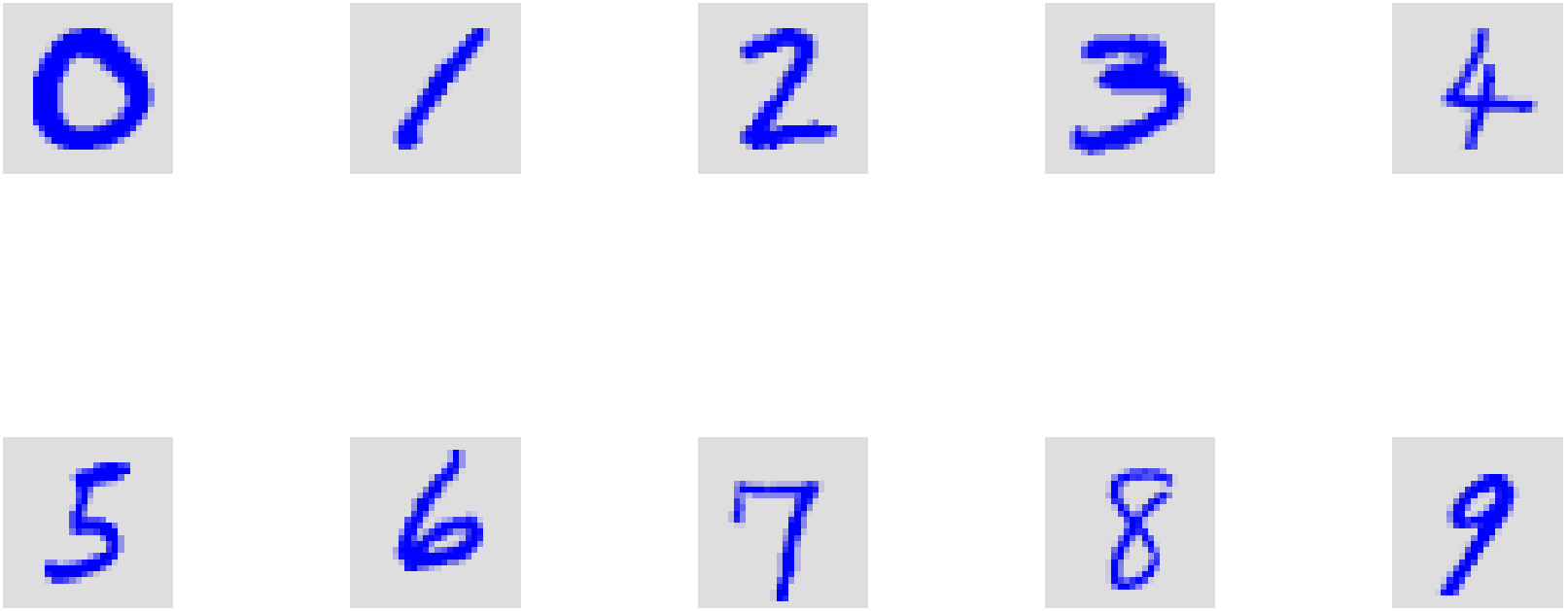
Representation

The function, f transfers an observation with 784 variables into an 28×28 image matrix.

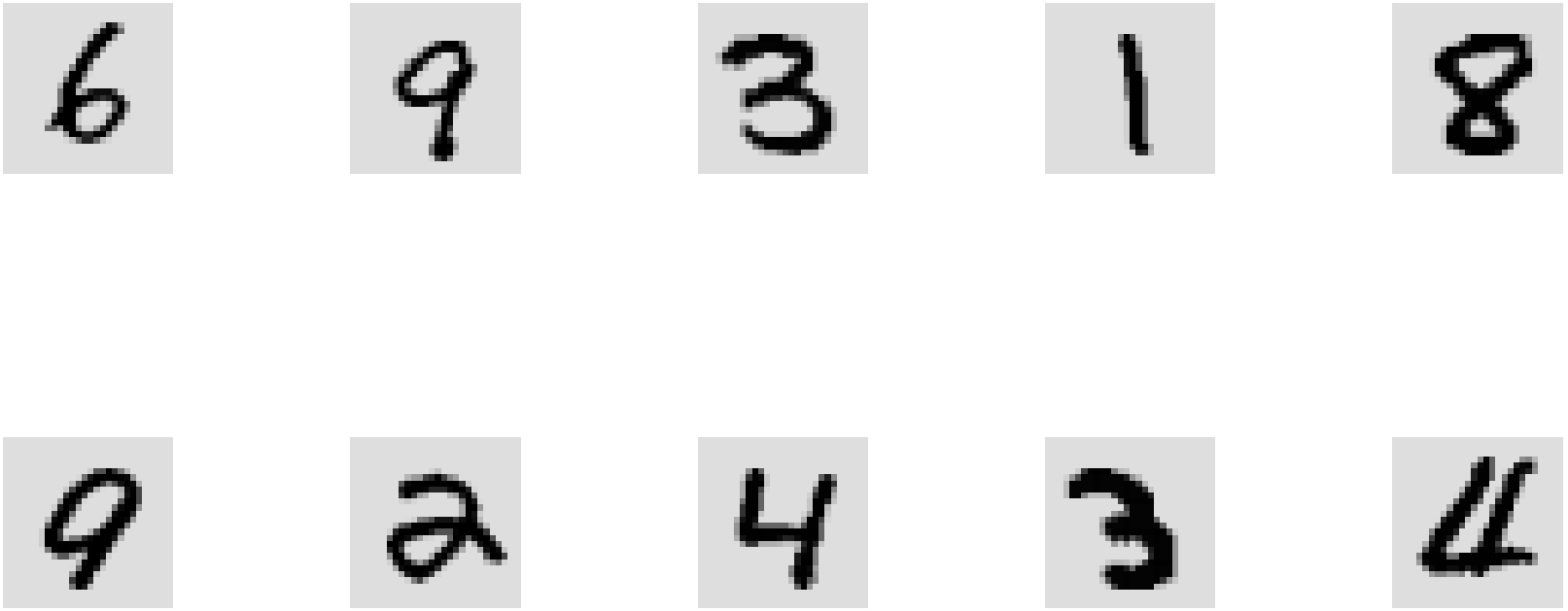
$$f : \mathbb{R}^{784} \rightarrow M_{28 \times 28}$$

$$M = \begin{bmatrix} \text{pixel}_{000} & \text{pixel}_{001} & \cdots & \text{pixel}_{027} \\ \text{pixel}_{028} & \text{pixel}_{029} & \cdots & \text{pixel}_{055} \\ \vdots & \vdots & \ddots & \vdots \\ \text{pixel}_{756} & \text{pixel}_{757} & \cdots & \text{pixel}_{783} \end{bmatrix}_{28 \times 28}$$

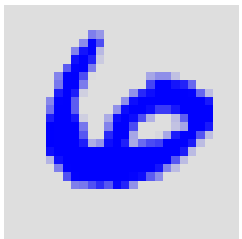
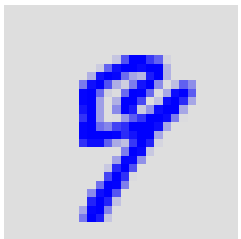
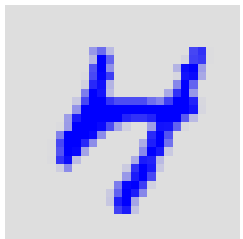
Images from the Training Data



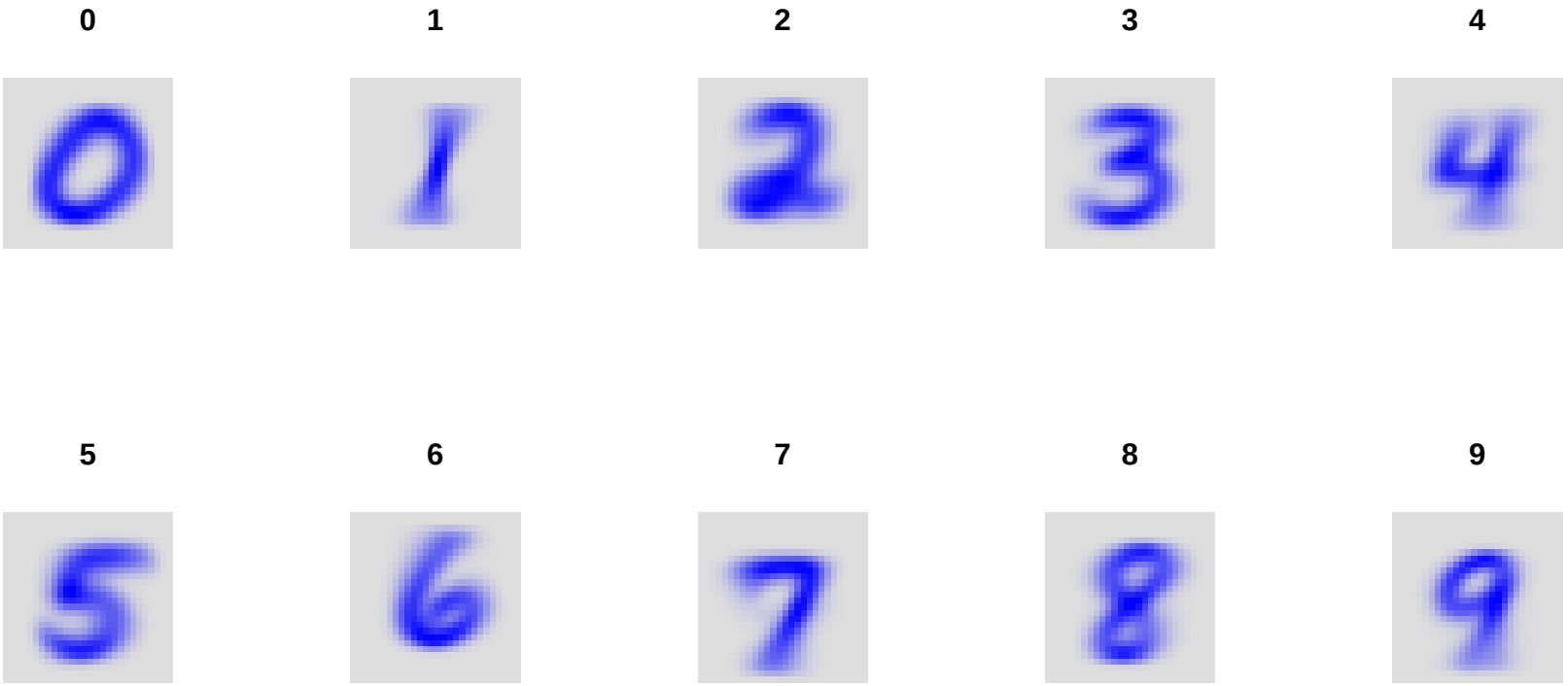
Images from the Test Data



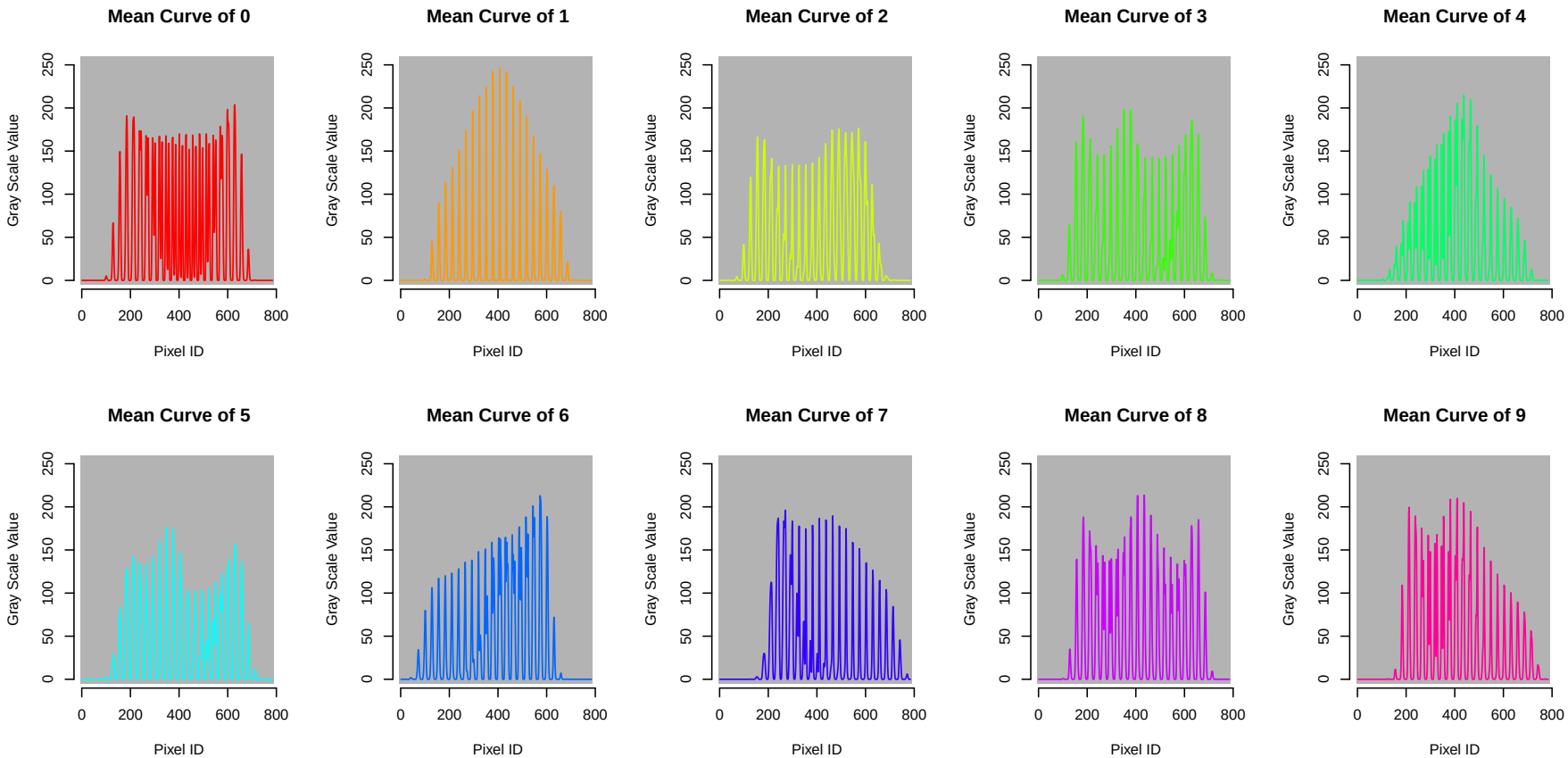
Some Naked-eyed Unrecognizable Images

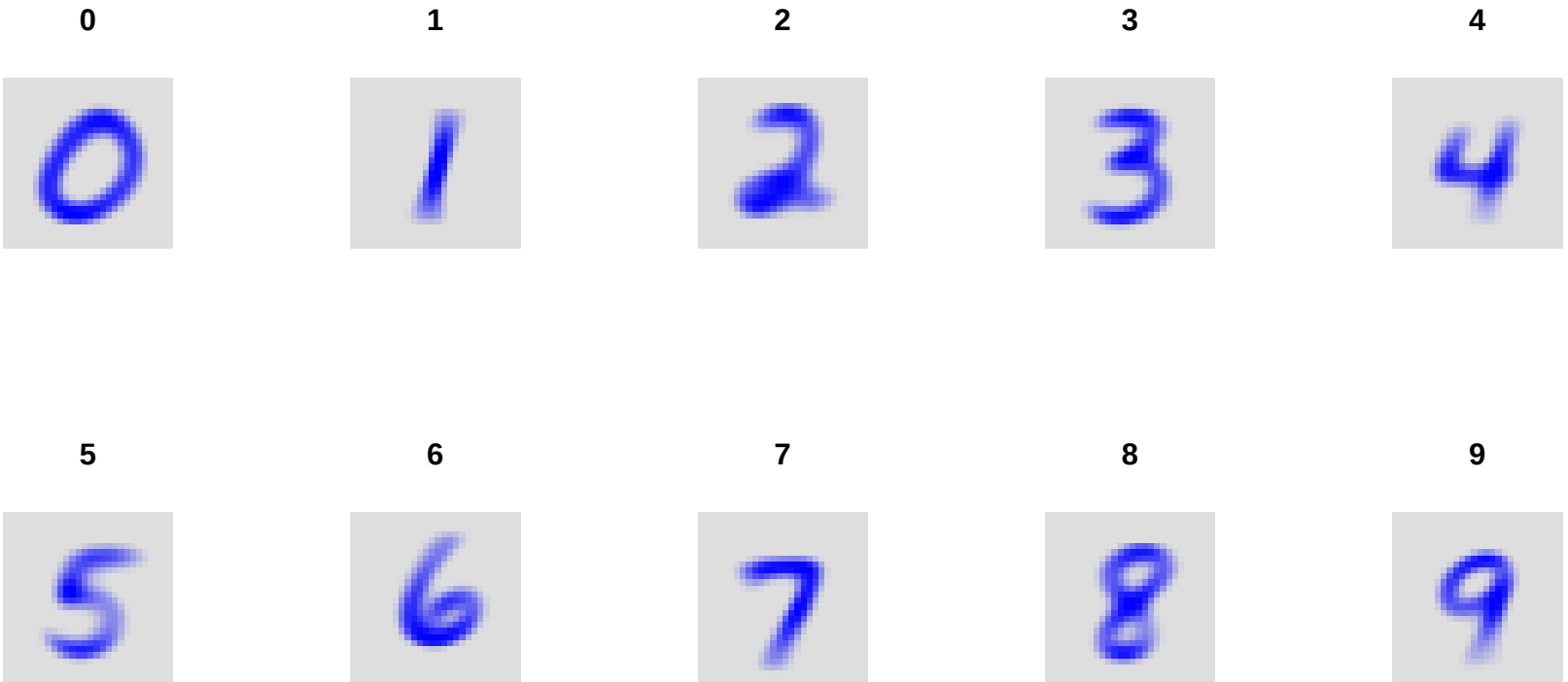
The Mean Images of the Different Digits



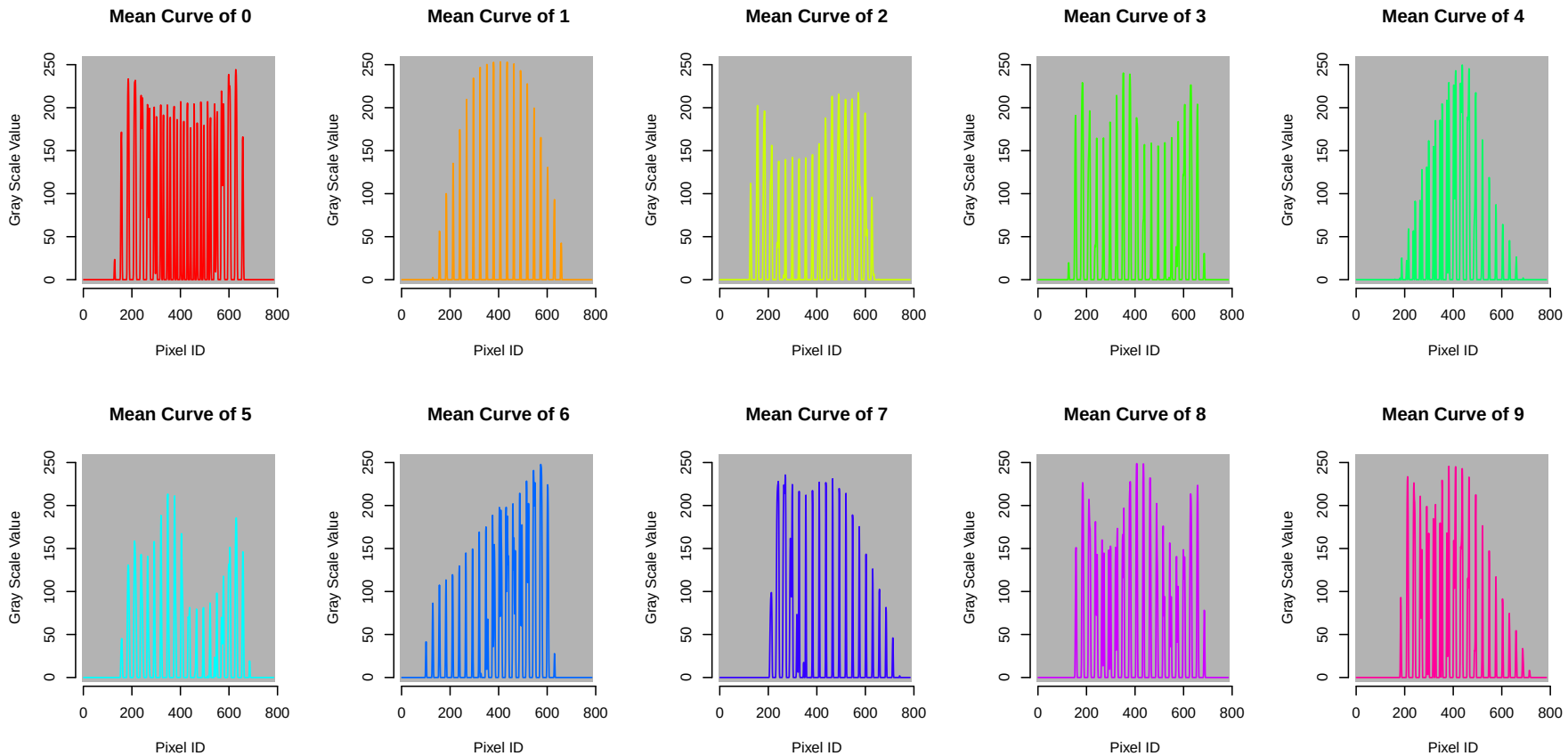
The Mean Curves of the Different Digits



The 20% Trimmed Mean Images of the Different Digits



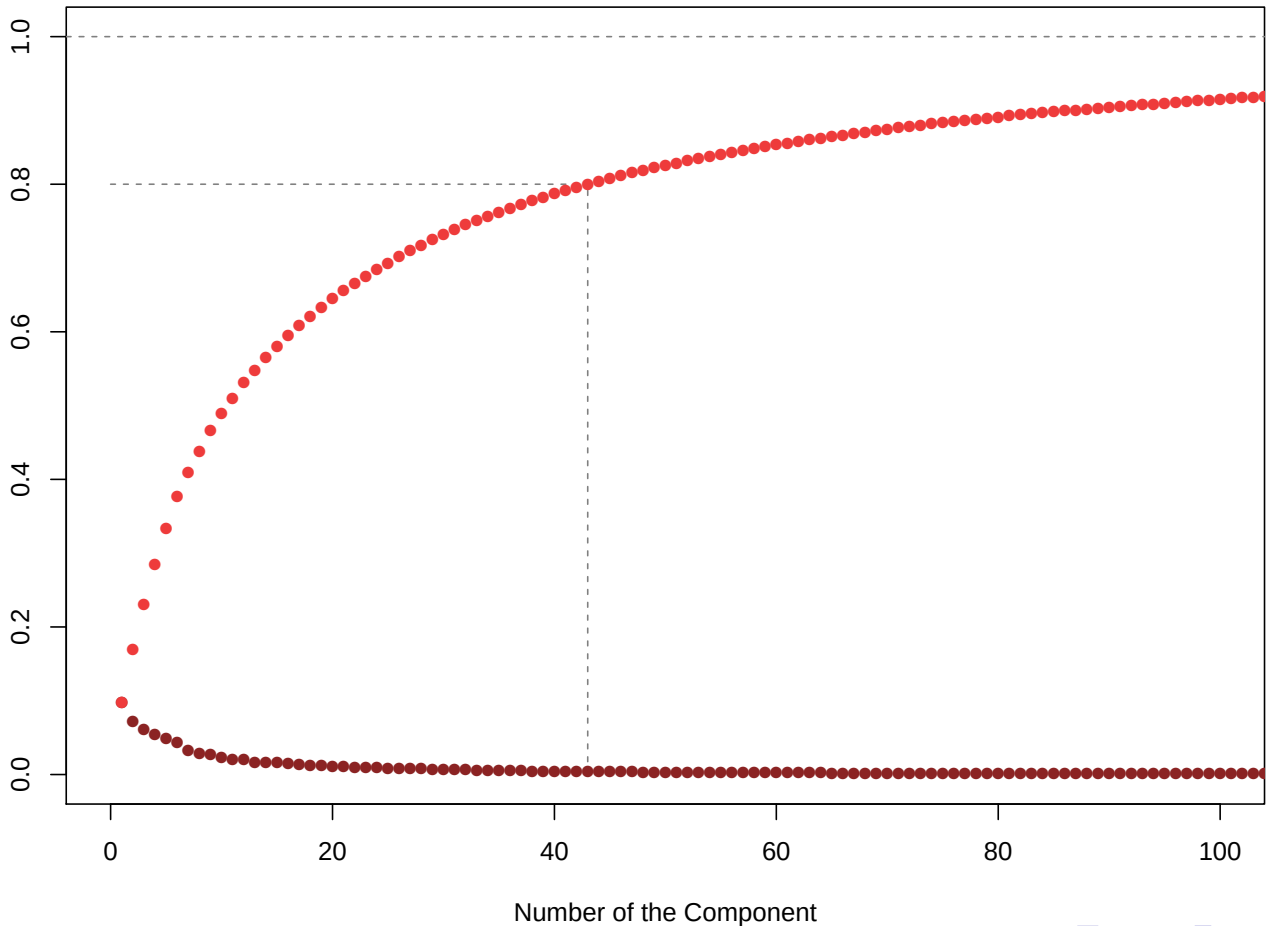
The 20% Trimmed Mean Curves of the Different Digits



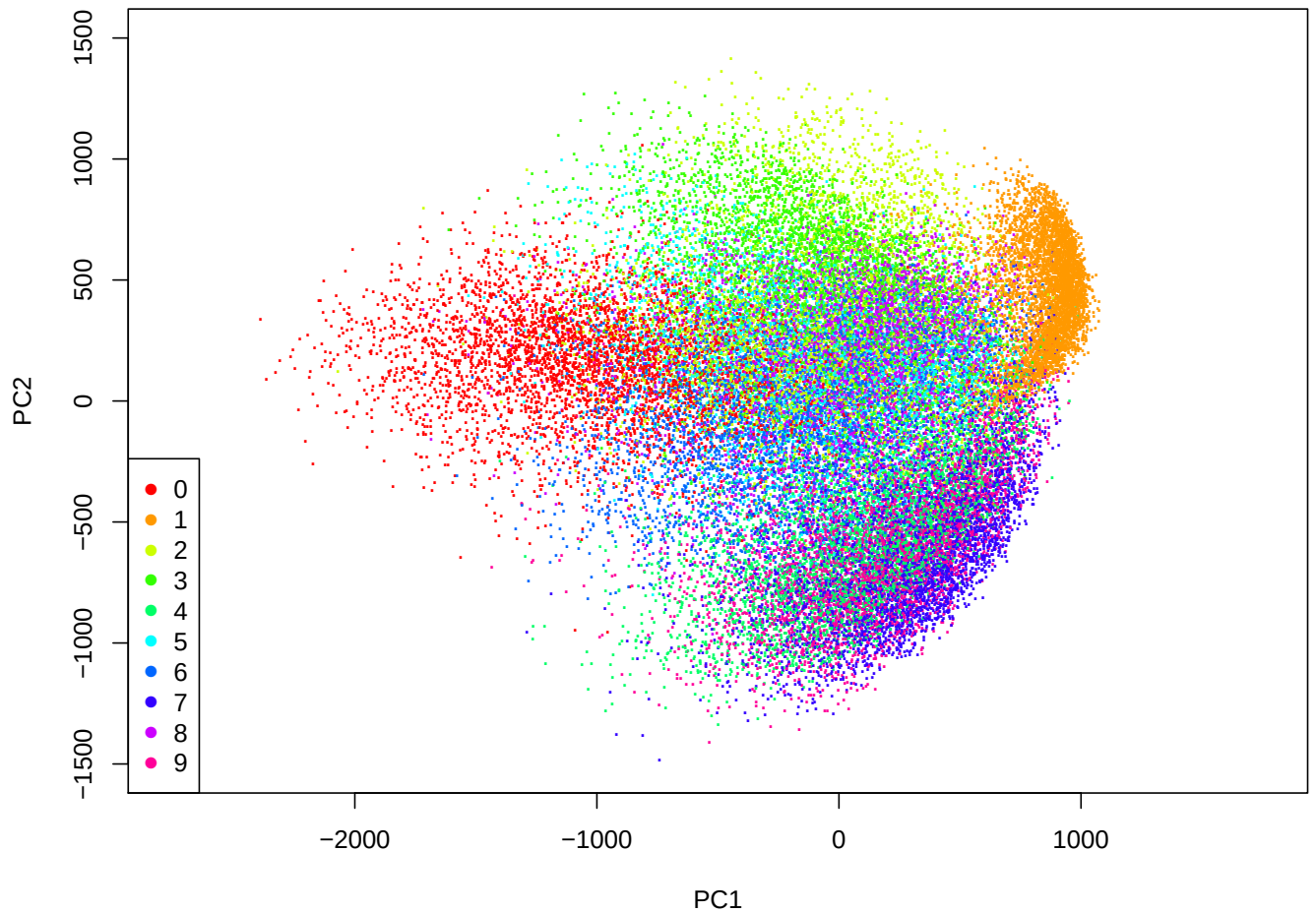
Coefficients for the Principal Component

	PC1	PC2	⋯	PC43	⋯	PC784
$pixel_0$	0.000	0.000	⋯	0.000	⋯	0.000
$pixel_1$	0.000	0.000	⋯	0.000	⋯	-0.072
⋮	⋮	⋮	⋱	⋮	⋱	⋮
$pixel_{462}$	0.075	-0.013	⋯	0.059	⋯	0.000
⋮	⋮	⋮	⋱	⋮	⋱	⋮
$pixel_{783}$	0.000	0.000	⋯	0.000	⋯	0.000
Variance	5.149	3.781	⋯	0.221	⋯	0.000
Cumulative Ratio of Total Variance	0.098	0.169	⋯	0.800	⋯	1.000

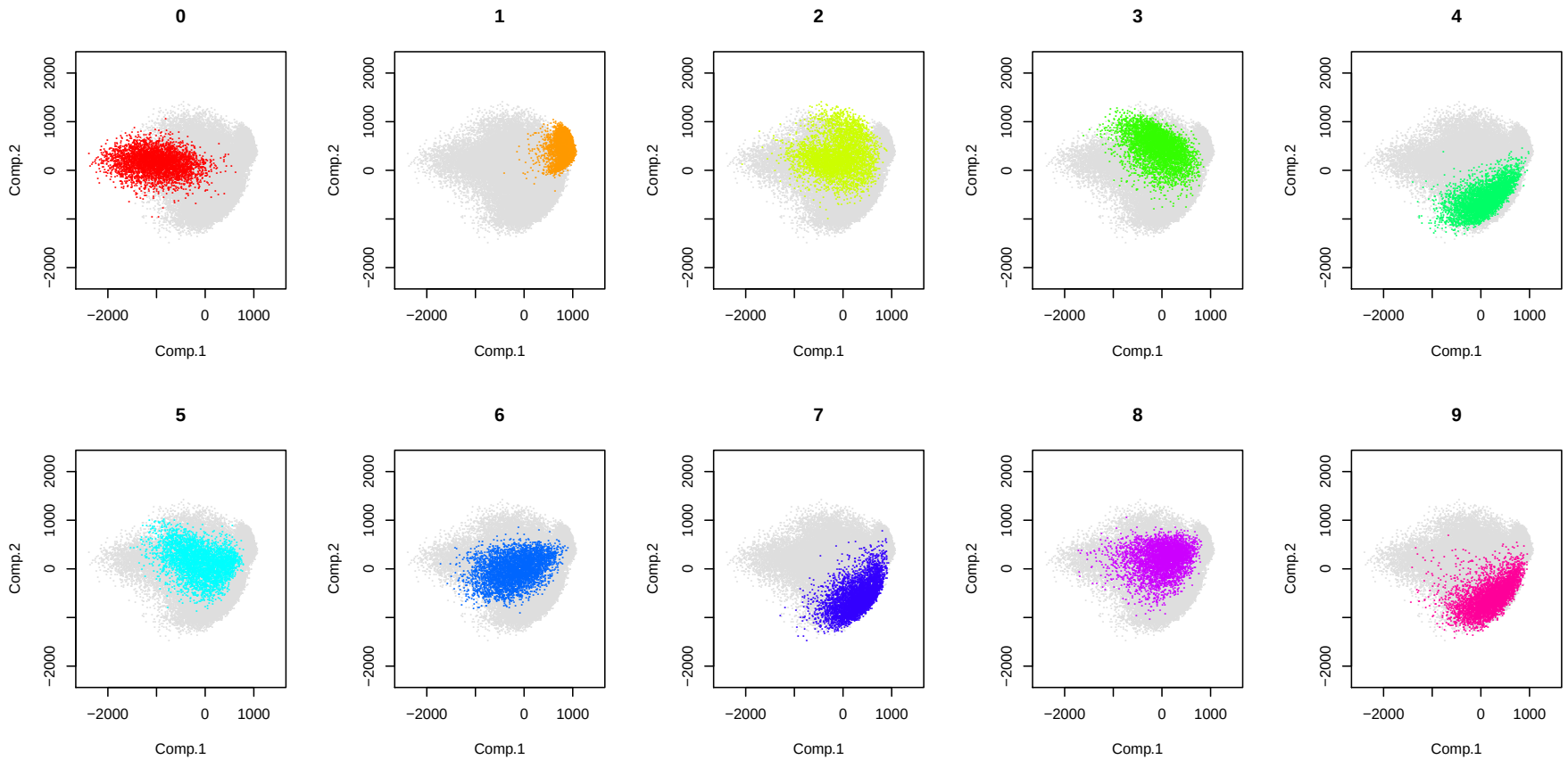
Cumulative Ratio of Total Variance



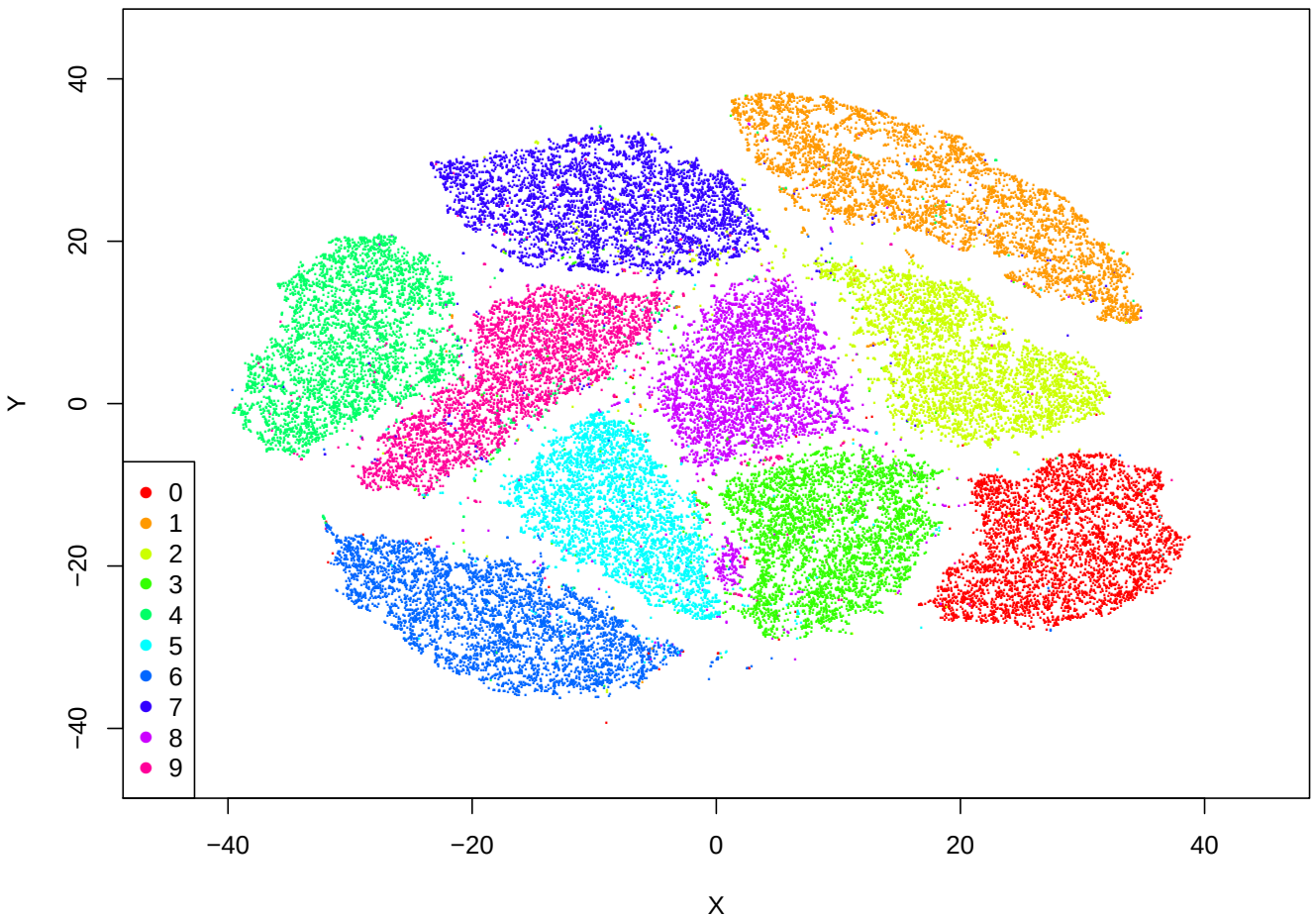
Scatter Plot for the First Two Components



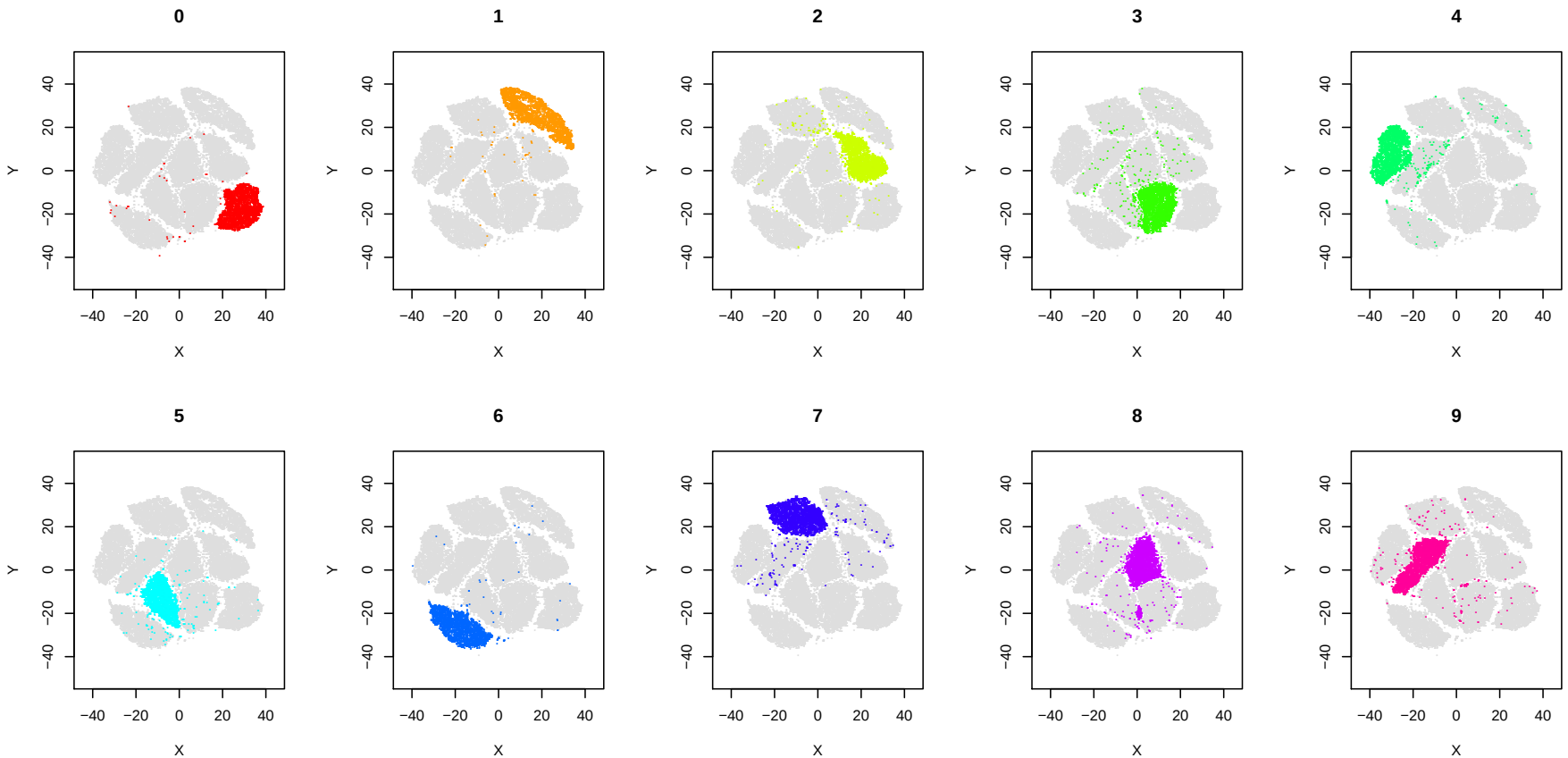
Separated Scatter Plot for the First Two Components



Two-dimensional t-SNE with 600-time Iterations

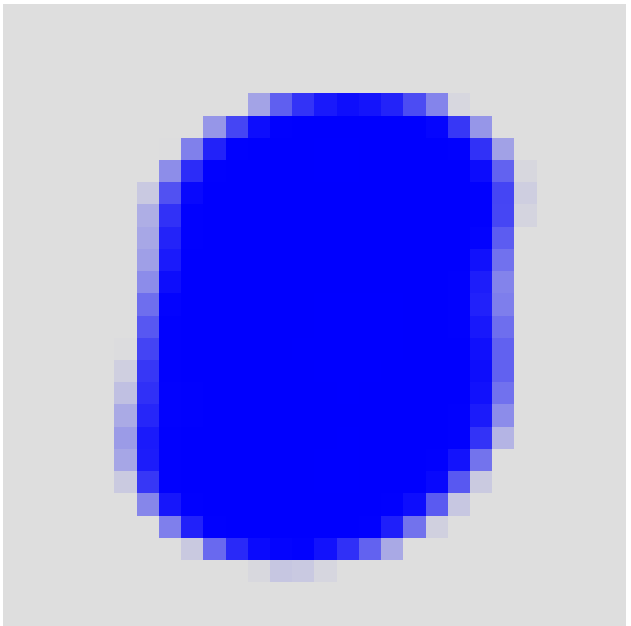


Separated Scatter Plot for the Two-dimensional t-SNE



Dimensionality Reduction

- Calculate the 90^{th} percentile
- Preserve those pixels with non-zero 90^{th} percentile
- 43.75% of pixels remain



One-versus-all Logistic Regression

		Prediction									
		0	1	2	3	4	5	6	7	8	9
Reality	0	944	7	4	9	7	1	2	1	0	0
	1	536	565	8	5	4	3	4	1	2	0
	2	331	291	274	13	11	10	15	10	3	1
	3	251	238	244	227	20	8	8	7	2	1
	4	206	173	174	196	198	14	4	5	4	5
	5	154	146	166	155	141	136	10	3	4	2
	6	185	135	140	116	131	142	122	0	1	0
	7	148	149	131	133	141	133	127	127	5	3
	8	130	120	127	105	108	109	78	111	77	1
	9	108	117	114	114	106	96	84	100	84	78

Table: Confusion Matrix (Accuracy = 27.48%)

K-Nearest Neighbor (KNN)

		Prediction									
		0	1	2	3	4	5	6	7	8	9
Reality	0	963	0	2	0	2	1	3	0	0	3
	1	0	1141	5	1	0	1	1	1	2	0
	2	6	7	979	4	1	0	1	15	1	2
	3	1	0	5	957	0	17	2	6	5	3
	4	0	8	0	0	957	0	6	2	0	32
	5	4	1	0	18	1	827	11	3	4	4
	6	5	0	1	0	3	4	957	0	0	0
	7	0	8	5	0	3	0	0	1025	0	7
	8	3	13	5	18	3	10	5	3	885	13
	9	3	3	2	6	15	2	1	19	2	955

Table: Confusion Matrix (Accuracy = 96.46%)

Support Vector Machine (SVM)

		Prediction									
		0	1	2	3	4	5	6	7	8	9
Reality	0	961	0	5	1	0	1	4	0	0	2
	1	0	1137	3	3	4	1	1	2	1	0
	2	2	1	995	1	2	1	0	5	9	0
	3	0	0	1	974	1	7	0	3	8	2
	4	0	3	0	0	987	0	3	0	1	11
	5	1	0	0	11	1	848	6	0	3	3
	6	4	0	1	0	3	4	957	0	1	0
	7	0	4	3	0	1	0	0	1034	1	5
	8	2	2	2	2	2	4	0	1	942	1
	9	2	2	4	6	8	1	1	4	4	976

Table: Confusion Matrix (Accuracy = 98.11%)

Multi-layer Perceptron (784-1000-1000-10 with ReLU)

		Prediction									
		0	1	2	3	4	5	6	7	8	9
Reality	0	974	1	0	2	0	0	1	1	1	0
	1	0	1128	2	0	0	0	3	0	2	0
	2	1	1	1020	4	1	0	1	3	1	0
	3	0	0	3	1000	0	2	0	3	0	2
	4	1	0	2	1	966	0	4	1	1	6
	5	2	0	0	11	1	873	4	0	0	1
	6	2	3	0	1	3	5	944	0	0	0
	7	0	6	11	2	0	1	0	1000	1	7
	8	0	0	3	13	2	5	4	3	938	6
	9	1	3	0	7	8	2	2	4	0	982

Table: Confusion Matrix (Accuracy = 98.25%)

Convolution Neural Network

		Prediction									
		0	1	2	3	4	5	6	7	8	9
Reality	0	976	1	0	0	0	0	1	1	1	0
	1	0	1134	0	1	0	0	0	0	0	0
	2	1	2	1027	0	0	0	0	2	0	0
	3	0	0	0	1005	0	3	0	0	2	0
	4	0	0	0	0	980	0	0	0	0	2
	5	0	0	0	5	0	886	1	0	0	0
	6	1	3	0	0	2	4	946	0	2	0
	7	0	3	5	1	0	0	0	1015	1	3
	8	1	0	2	3	1	2	0	1	961	3
	9	0	2	0	1	5	3	0	1	0	997

Table: Confusion Matrix (Accuracy = 99.27%)

Predict Instantly Online

- `https://goo.gl/Ac1aXg`
- Train the MLP with Keras on Python
- Export the weight matrices and bias vectors as JavaScript file
- Insert the matrices into JavaScript
- Mobilized the model

Q & A

Thank you for listening