Digit Recognition

with Support Vector Machines

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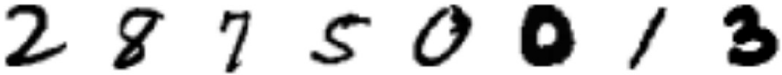
Outline

1. Introduction to Our Data Set
2. Our Approach
3. Sequential Minimal Optimization (SMO)
4. Multi-Class Classification
5. Results & Conclusions

Introduction to Our Data Set

Main Goal: train algorithm to recognize handwritten digits

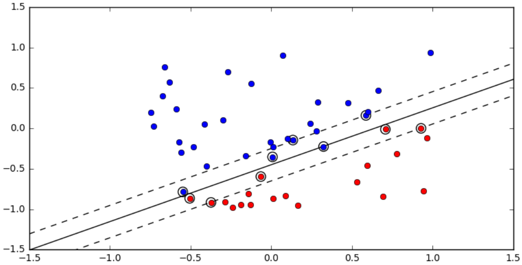


Data:

- 42,000 greyscale images
- 28 by 28 pixels each
- partitioned into ten classes

Our Approach

We want to use the concept of SVMs.



- **Problem I:** SVMs are binary classifiers
- **Problem II:** Need to solve optimization problem

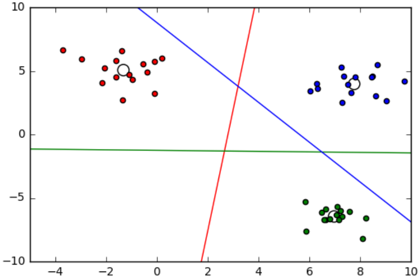
Our Approach

1. Implement solver for our QP
   - 3 versions
2. Implement basic SVM algorithm
   - linear kernel / Gaussian kernel
   - Parameter optimization
3. Combine individual SVMs in different ways
   - 3 versions
4. Validate and compare results

Sequential Minimal Optimization (SMO)

Multi-Class Classification

- Choose k groups of the classes
- Train k SVMs that separate each group from the rest
- Compare outcome to what would arise for each digit.
- **Problem:** Points may not be classified uniquely.
- Handle overlappings by minimizing distance to barycenters



Multi-Class Classification

1. One-vs-All

Idea: For each $i \in \{0, 1, \ldots, 9\}$, train an SVM that separates class i from the rest

Class	f_0	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9
0	–1	1	1	1	1	1	1	1	1	1
1	1	–1	1	1	1	1	1	1	1	1
2	1	1	–1	1	1	1	1	1	1	1
3	1	1	1	–1	1	1	1	1	1	1
4	1	1	1	1	–1	1	1	1	1	1
5	1	1	1	1	1	–1	1	1	1	1
6	1	1	1	1	1	1	–1	1	1	1
7	1	1	1	1	1	1	1	–1	1	1
8	1	1	1	1	1	1	1	1	–1	1
9	1	1	1	1	1	1	1	1	1	–1

2. Error Correcting Output Codes

Idea: Relabeling with large Hamming distance according to:

Class	f_0	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}
0	1	1	−1	−1	−1	−1	1	−1	1	−1	−1	1	1	−1	1
1	−1	−1	1	1	1	1	−1	1	−1	1	1	−1	−1	1	−1
2	1	−1	−1	1	−1	−1	−1	1	1	1	1	−1	1	−1	1
3	−1	−1	1	1	−1	1	1	1	−1	−1	−1	−1	1	−1	1
4	1	1	1	−1	1	−1	1	1	−1	−1	1	1	−1	−1	1
5	−1	1	−1	−1	1	1	−1	−1	1	1	−1	−1	−1	−1	1
6	1	−1	1	1	1	−1	−1	−1	−1	1	−1	1	−1	−1	1
7	−1	−1	−1	1	1	1	1	−1	1	−1	1	1	−1	−1	1
8	1	1	−1	1	−1	1	1	−1	−1	1	−1	−1	−1	1	1
9	−1	1	1	1	−1	−1	−1	−1	1	−1	1	−1	−1	1	1

Results & Conclusions

# training points	One-vs-All uniquely classfied, linear	One-vs-All with bary-centers, linear	One-vs-All uniquely classfied, Gaussian	One-vs-All with bary-centers, Gaussian	ECOC, linear	ECOC, Gaussian
500						
1000						
2000						
5000						
10000						

Table: Correctly Classified Digits

Results & Conclusions

# training points	One-vs-All uniquely classfied, linear	One-vs-All with bary-centers, linear	One-vs-All uniquely classfied, Gaussian	One-vs-All with bary-centers, Gaussian	ECOC, linear	ECOC, Gaussian
500	65.9%	74.1%	75.4%	83.3%	74.2%	87.4%
1000	68.2%	75.0%	84.3%	89.0%	78.0%	92.7%
2000	70.2%	76.4%	89.8%	91.9%	77.8%	94.3%
5000	70.0%	73.8%	88.9%	91.6%	82.0%	95.2%
10000	64.6%	67.5%	88.0%	90.6%	82.5%	95.4%

Table: Correctly Classified Digits

Results & Conclusions

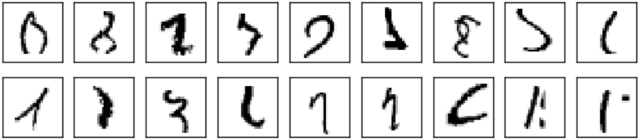


Figure: Visualizing very illegible digits