**Toy Example**

We have a dataset $D_1$ represented by the following pattern:

```
+  +  -
+  +  -
+  -  -
+  -  -
```

**weak hypotheses = vertical or horizontal half-planes**
Round 1

\[ h_1 \]

\[ D_2 \]

\[ \varepsilon_1 = 0.30 \]
\[ \alpha_1 = 0.42 \]
Round 2

\[ \varepsilon_2 = 0.21 \]
\[ \alpha_2 = 0.65 \]
Round 3

\[ \alpha_3 = 0.92 \]

\[ \varepsilon_3 = 0.14 \]
Final Hypothesis

\[ H_{\text{final}} = \text{sign} \left( \begin{array}{c}
0.42 \\
+ 0.65 \\
+ 0.92
\end{array} \right) \]
Actual Typical Run

(boosting C4.5 on “letter” dataset)

- test error does not increase, even after 1000 rounds
  - (total size > 2,000,000 nodes)
- test error continues to drop even after training error is zero!

<table>
<thead>
<tr>
<th># rounds</th>
<th>5</th>
<th>100</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>train error</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>test error</td>
<td>8.4</td>
<td>3.3</td>
<td>3.1</td>
</tr>
</tbody>
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- Occam’s razor wrongly predicts “simpler” rule is better
The Margin Distribution

- margin distribution

= cumulative distribution of margins of training examples

![Graph showing error and margin distribution](image)

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<tr>
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<td>3.3</td>
<td>3.1</td>
</tr>
<tr>
<td>% margins ≤ 0.5</td>
<td>7.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>minimum margin</td>
<td>0.14</td>
<td>0.52</td>
<td>0.55</td>
</tr>
</tbody>
</table>
Application: Detecting Faces

- problem: find faces in photograph or movie
- weak hypotheses: detect light/dark rectangles in image

- many clever tricks to make extremely fast and accurate