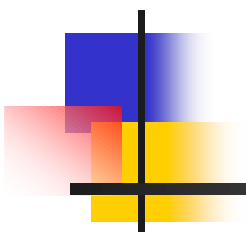

SENSITIVITY EXPERIMENTS ON ONE-CLASS SUPPORT VECTOR MACHINE

SAMO 2007

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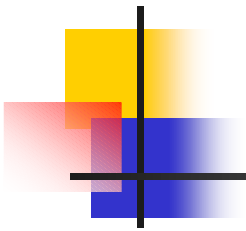
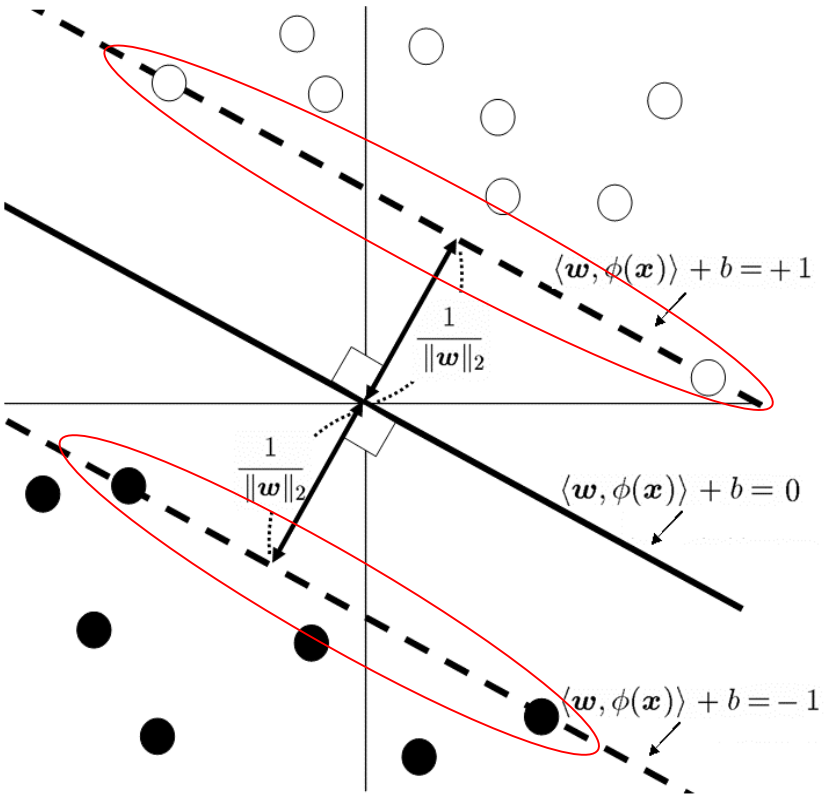


Plan of Talk

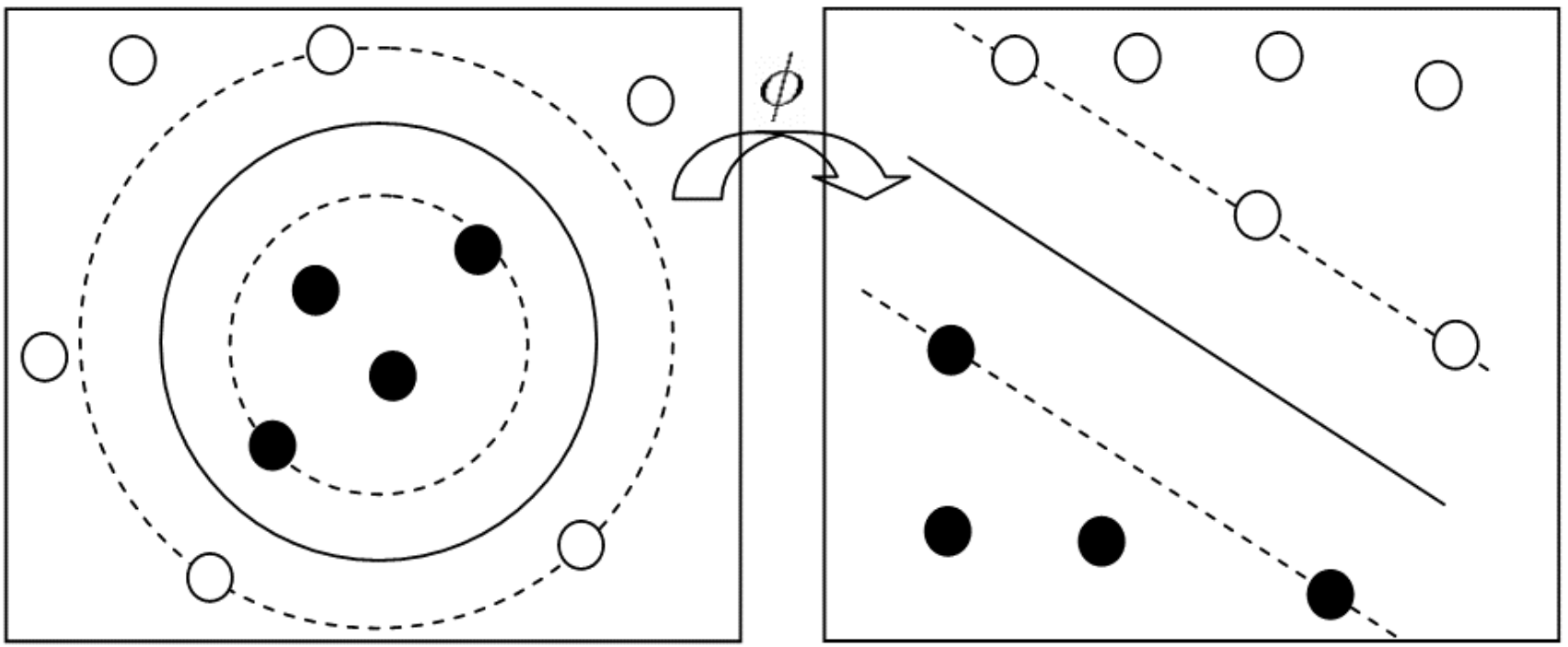
- SVM (Support Vector Machine)
- One-Class SVM (1-SVM)
- Sensitivity Experiments
- Semiconductor Application
- Conclusions
- References

SVM (Support Vector Machine)

- Binary Classification
- Formulation as LP
- Support Vectors
- Kernel Trick



Kernel Trick



$$x_1, x_2, \cdots x_n \in \chi^R$$

$$\phi(x_1)^T \phi(x_2) = K(x_1, x_2)$$

One Class SVM (1-SVM)

Primary

$$\min_{\boldsymbol{w},\rho,\boldsymbol{\xi}} \quad \frac{1}{2}\|\boldsymbol{w}\|_2^2 - \nu n\rho + \sum_{i=1}^{n}\xi_i$$

$$\text{s.t.} \quad \langle \boldsymbol{w}, \phi(\boldsymbol{x}_i)\rangle \geq \rho - \xi_i$$

$$\xi_i \geq 0, \qquad i = 1, \ldots, n.$$

Dual

$$\min_{\boldsymbol{\alpha}} \quad \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_i\alpha_j K(\mathbf{x}_i, \mathbf{x}_j)$$

$$\text{s.t.} \quad 0 \leq \alpha_i \leq \frac{1}{\nu n}, \qquad \sum_{i=1}^{n}\alpha_i = 1$$

KKT Conditions (1-SVM)

Support Vectors: x_i are training data corresponding to $\alpha_i \neq 0$

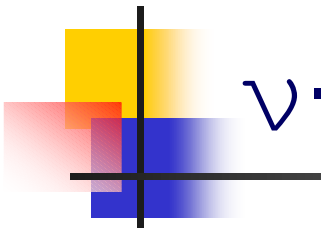
$$\alpha_i = 0 \quad \Rightarrow \quad f(\mathbf{x}_i) \geq 0 \quad \text{and} \quad \xi_i = 0 \qquad \textbf{Regular}$$

$$0 < \alpha_i < \frac{1}{\nu n} \quad \Rightarrow \quad f(\mathbf{x}_i) = 0 \quad \text{and} \quad \xi_i = 0 \qquad \textbf{Boundary}$$

$$\alpha_i = \frac{1}{\nu n} \quad \Rightarrow \quad f(\mathbf{x}_i) < 0 \quad \text{and} \quad \xi_i > 0 \qquad \textbf{Outlier}$$

$$\min_{\boldsymbol{\alpha}} \quad \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_i \alpha_j K(\mathbf{x}_i, \mathbf{x}_j)$$

$$\text{s.t.} \quad 0 \leq \alpha_i \leq \frac{1}{\nu n}, \quad \sum_{i=1}^{n} \alpha_i = 1$$

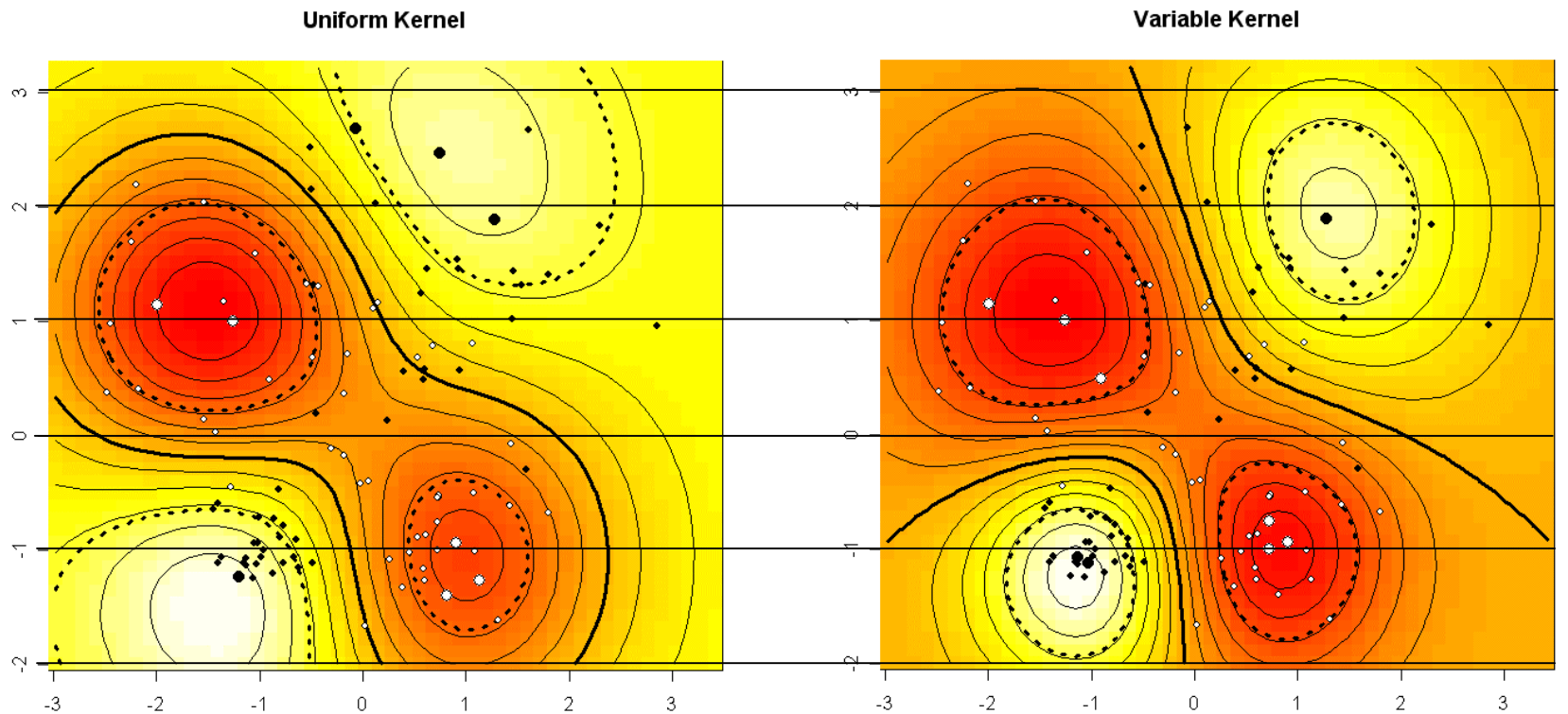


ν-Property

$$\frac{1}{n}\sum_{i=1}^{n} I[f(\boldsymbol{x}_i) < \rho^*] \leq \nu \leq \frac{1}{n}\sum_{i=1}^{n} I[f(\boldsymbol{x}_i) \leq \rho^*]$$

Outlier **Boundary + Outlier**

Outlier & Support Vectors



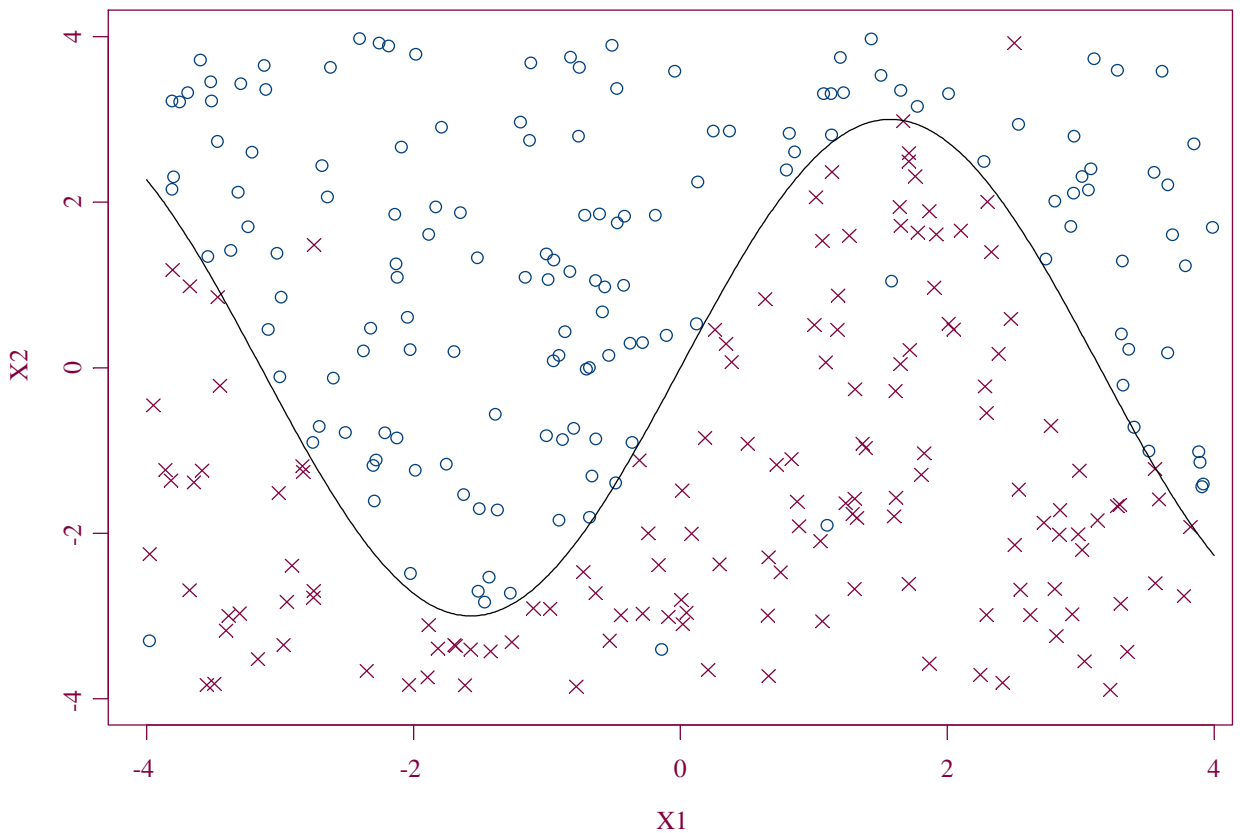
Sensitivity Studies

Sensitivity of 1-SVM performance with respect to ν for **noisy mislabeled data**.

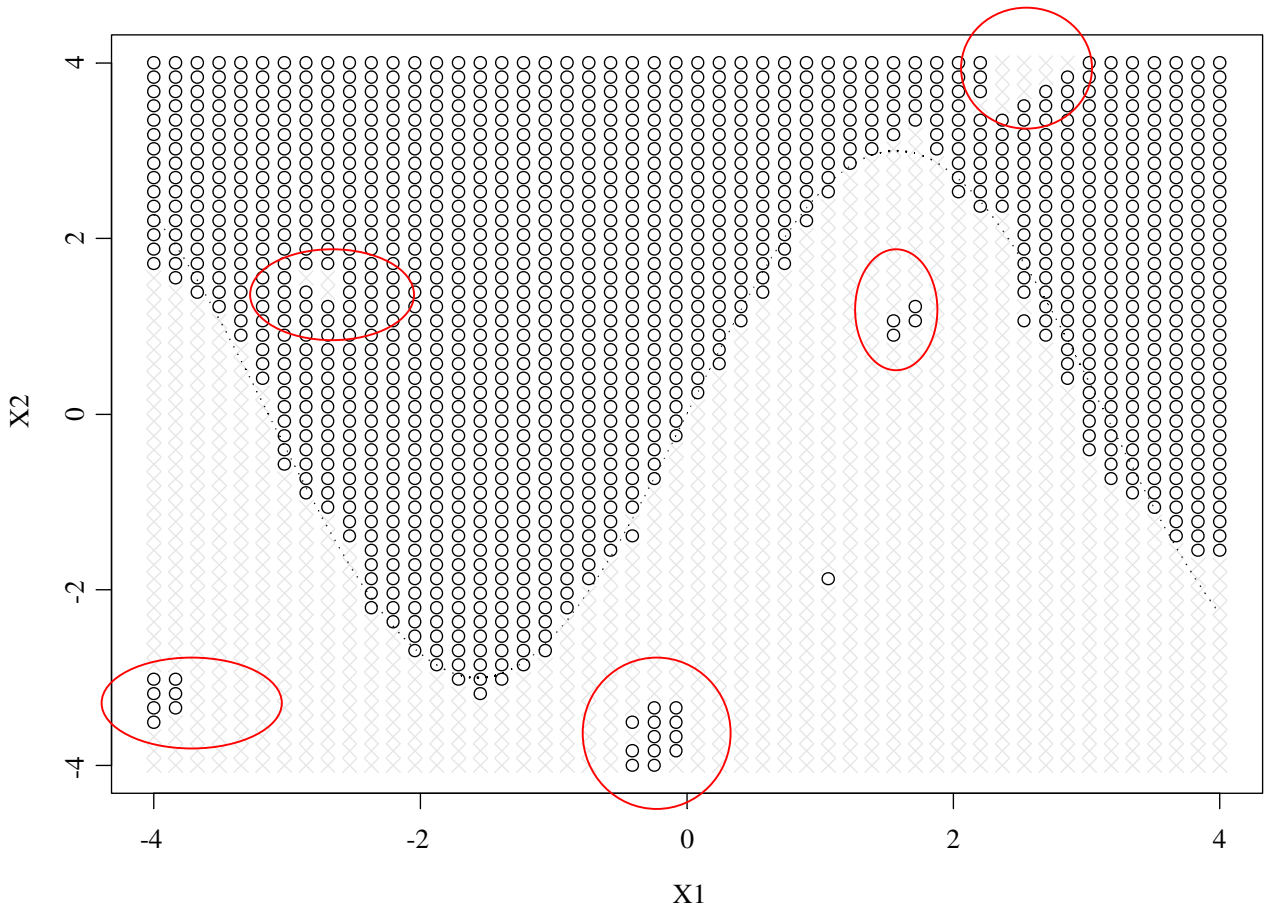
$$\begin{aligned} \min_{\boldsymbol{w},\rho,\boldsymbol{\xi}} \quad & \frac{1}{2}\|\boldsymbol{w}\|_2^2 - \nu n\rho + \sum_{i=1}^{n} \xi_i \\ \text{s.t.} \quad & \langle \boldsymbol{w}, \phi(\boldsymbol{x}_i) \rangle \geq \rho - \xi_i \\ & \xi_i \geq 0, \qquad i = 1, \ldots, n. \end{aligned}$$

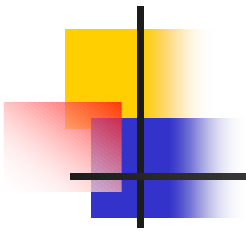
Noisy Mislabeled Data

Example: 2% Mislabeled



Resulting Decision Boundary

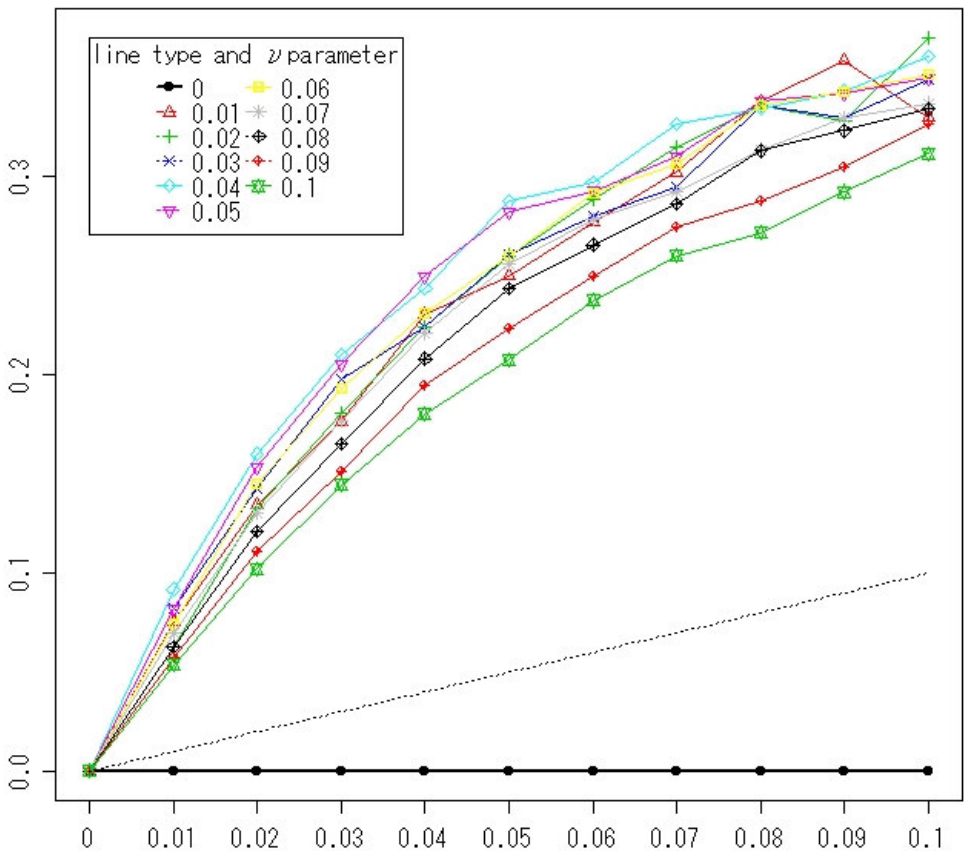




Experiments

- **UCI Machine Learning Repository**
  - Breast Cancer (9-dim. 683 data)
  - Heart (13-dim. 270 data)
  - Ionosphere (33-dim. 351 data)
- **Gaussian kernel is used.**
- **ν is the parameter.**

1-SVM Performance (Gain Chart)

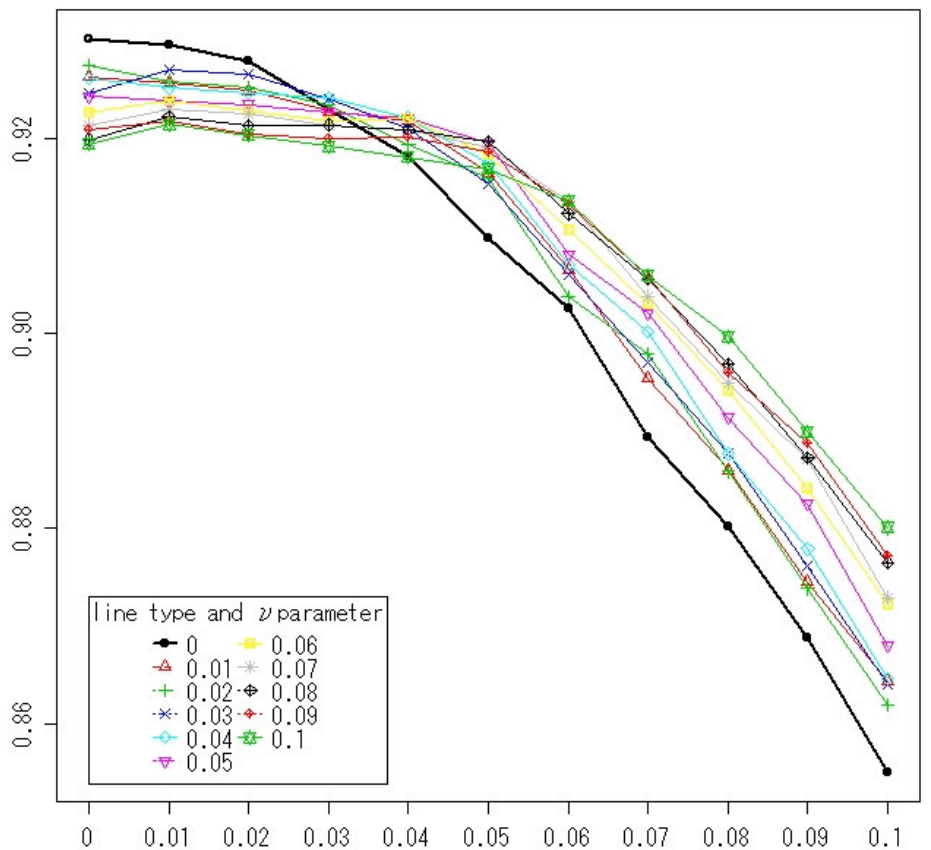


Outlier=Mislabeled Data

x-axis: rate of mislabeled data

y-axis: mislabeled data/outlier

Sensitivity Experiment 1

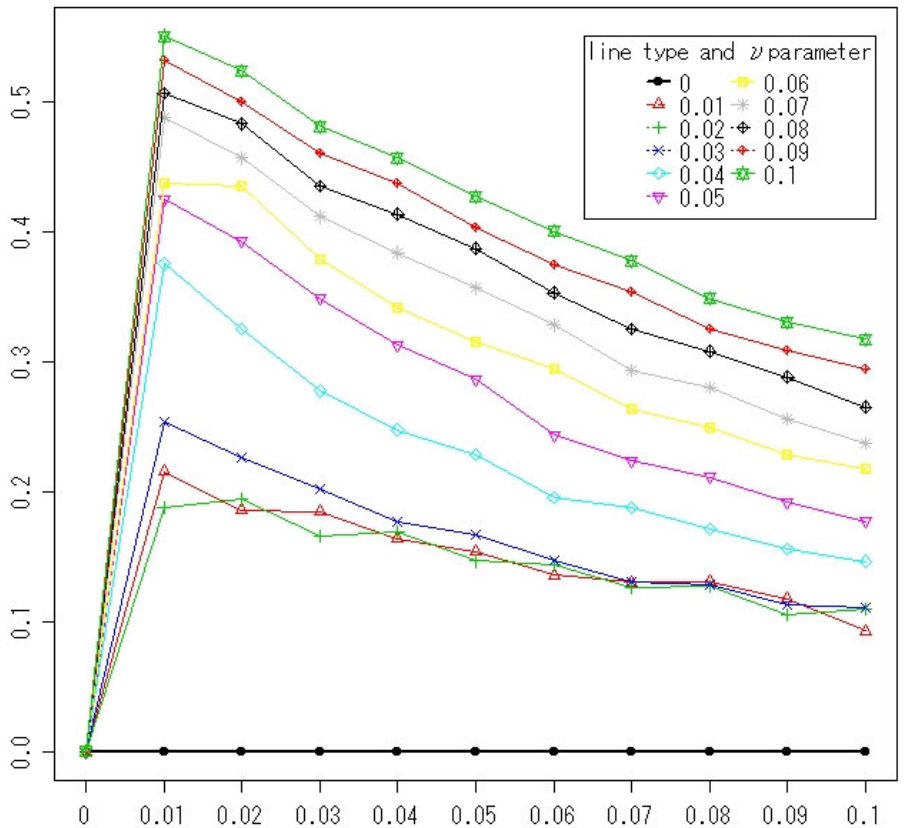


Outlier=Mislabeled Data

x-axis: rate of mislabeled data

y-axis: accuracy

Sensitivity Experiment 2

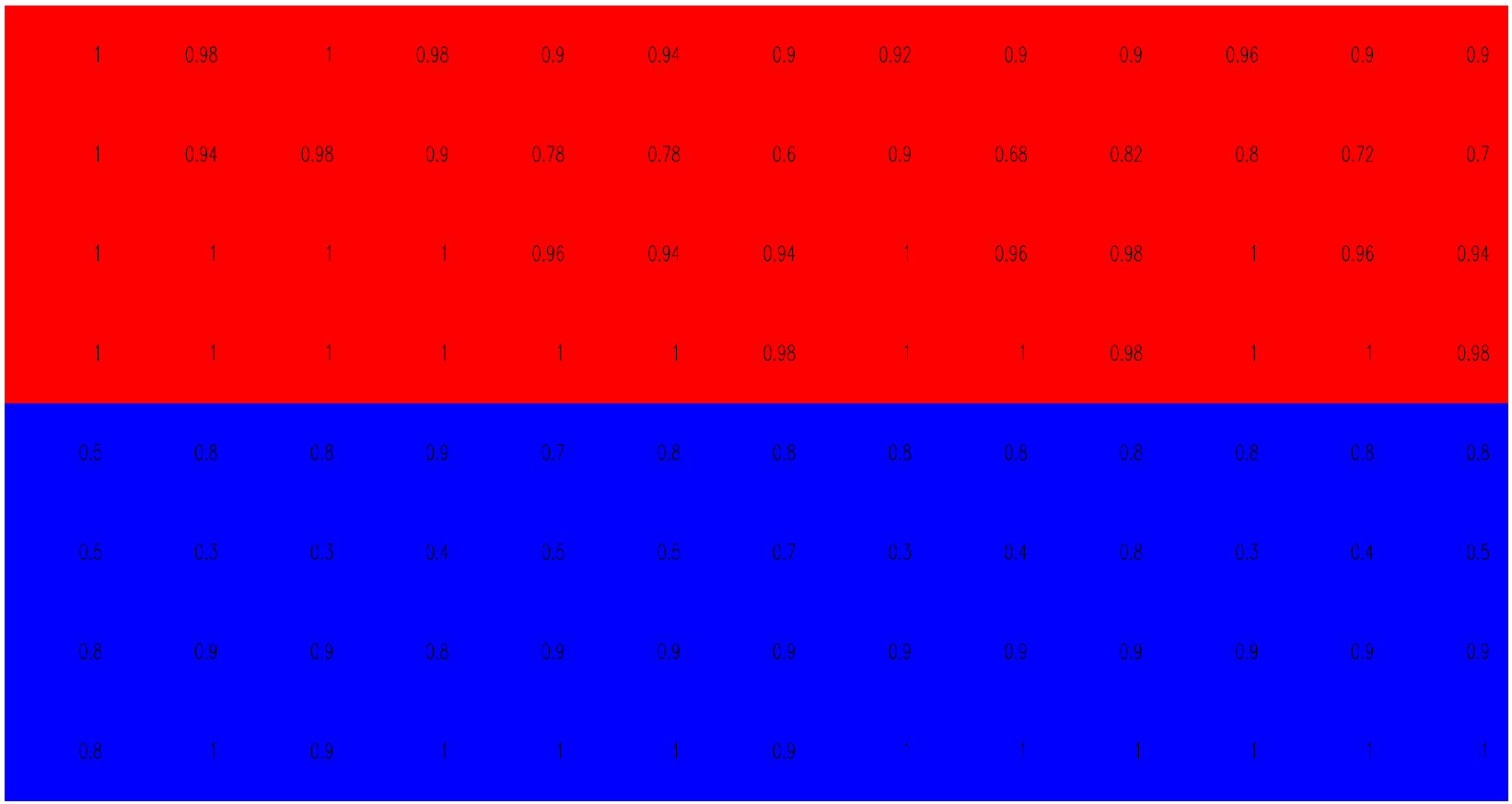


Outlier=Mislabeled Data

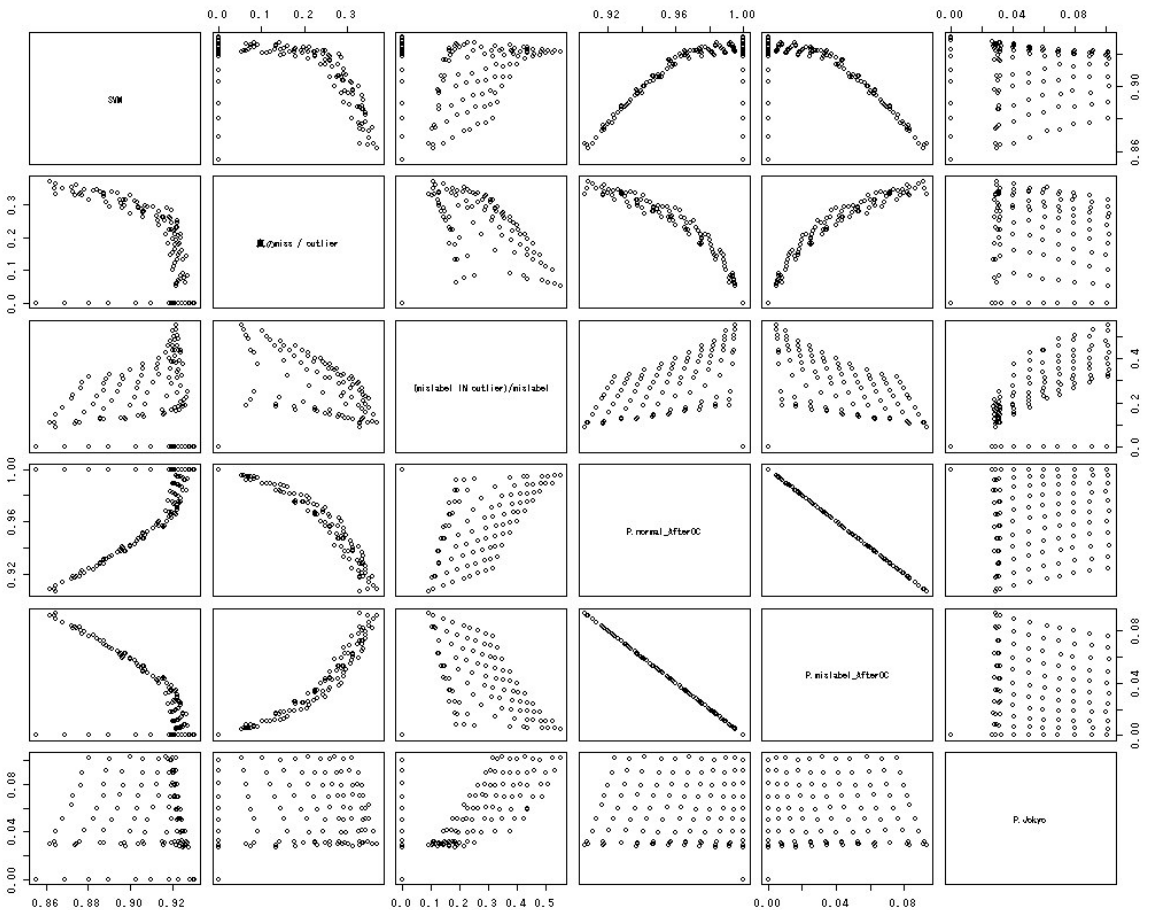
x-axis: rate of mislabeled data

y-axis: mislabeled data removal

Semiconductor Application

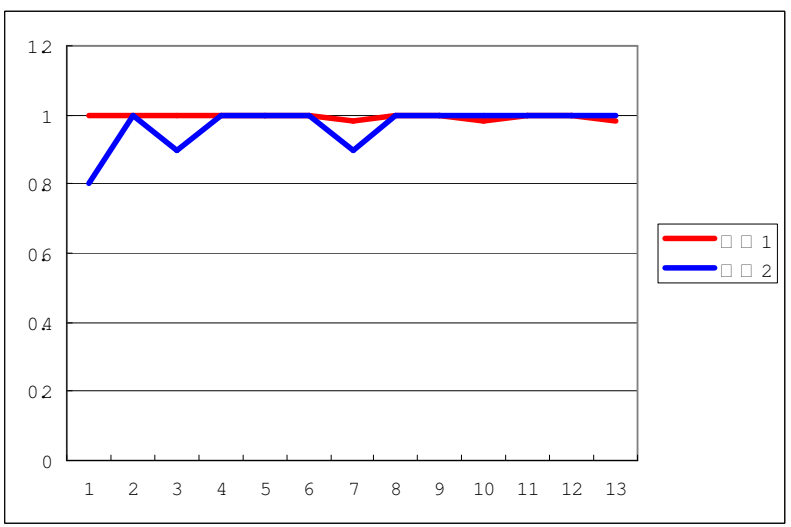


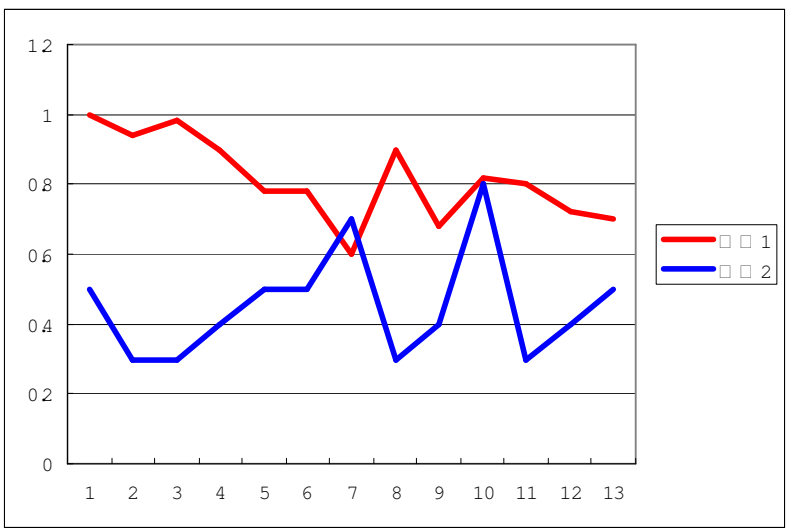
Semiconductor process



Semiconductor Results

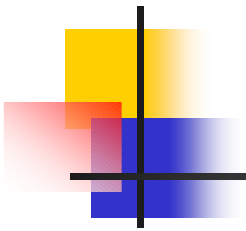
1-SVM is used as a preprocessor to remove outliers for noisy mislabeled data.





Conclusions

- 1-SVM can be used as a preprocessor to remove mislabeled data as outliers with accuracy improvement of 3%~4%.
- Sensitivity experiment may be effective to choose optimal value of ν for 1-SVM.
- The proposed method can work in real semiconductor applications.



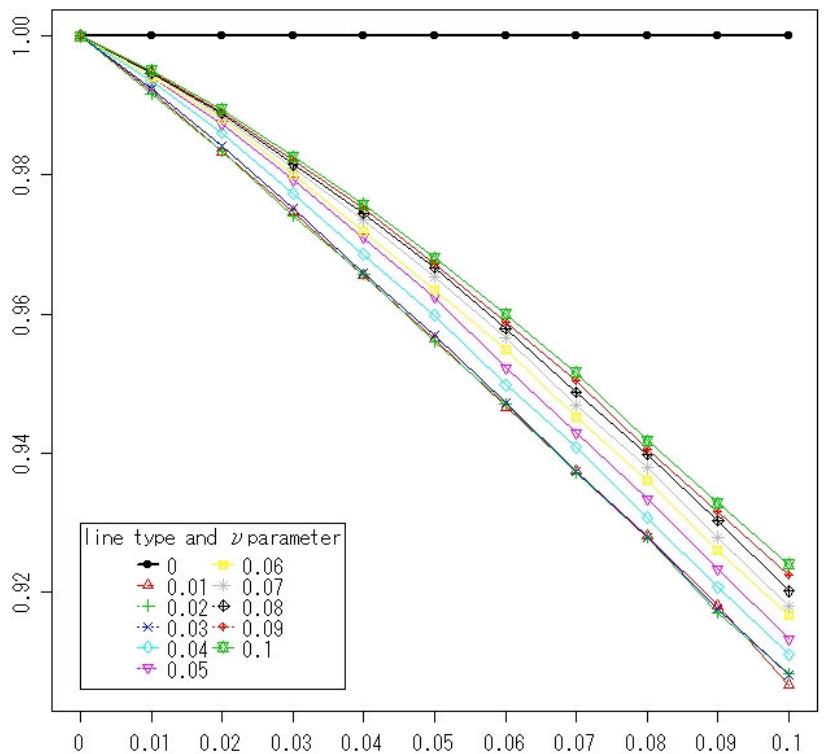
References

Ratsch, G., Mika, S., Scholkopf, B., Muller, K., "Constructing Boosting Algorithms from SVMs: an Application to One-Class Classification", IEEE Trans, Pattern Analysis and Machine Intelligence, Vol. 24, pp. 1184-1199, 2002.

Scholkopf, B., Smola, A.J., Williamson, R.C., Bartlet, P.L., "New Support Vector Algorithms", Neural Computation, Vol. 12, pp. 1207-1245, 2000.

Takabatake, T., Koda, M., "1-SVM and Domain Classification with Neighbor Support (in Japanese)", Trans. Operations Research Society of Japan, Vol.51, pp. 677-682, 2006.

Experimental result 4



4 rate of normal data after the OC-SVM

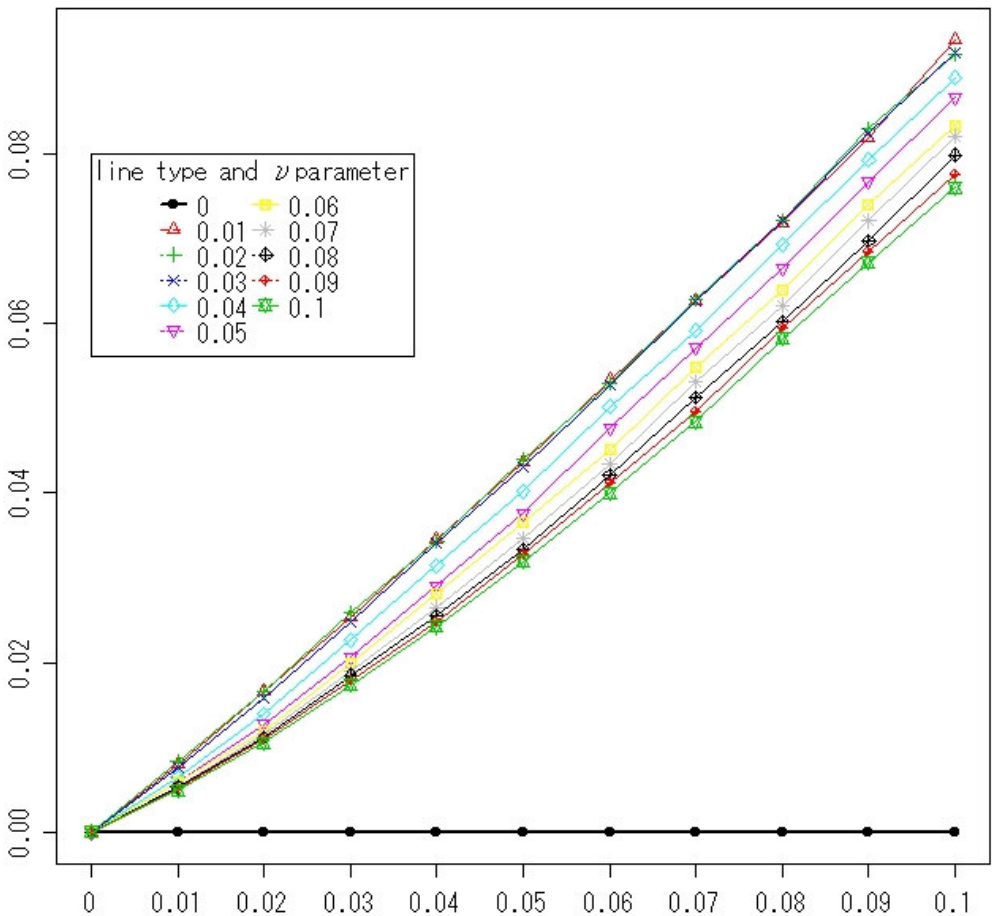
normal…(in OC..train…)/OC..train…

.OC..training……normal……

x. rate of mislabel

y. rate of normal data

Experimental result 5



5 rate of mislabel data after the OC-SVM

mislabel…(in OC..train…)/OC..train…

.OC..training……mislabel……

x. rate of mislabel

y. rate of normal data