Corrections and Changes to Machine Learning: a Concise Introduction
Through 12/12/2018

The significance of changes is denoted by a scale of one to three stars:

★★★ --- an error which could mislead an informed reader;
★★ --- an error which many readers would notice and correct;
★ --- a small change to enhance clarity or consistency, or to correct grammar.

The color of the stars is just a reminder to the author, and is not otherwise meaningful.

★ *Page 5, Section 2.3 (Data), second paragraph*

It is sometimes useful to consider the data as produced by a two-step process, in one of two ways: by drawing Y from marginal distribution $\mathrm{P}(Y)$ on $f(\mathcal{X})$ and then drawing a corresponding feature vector X from conditional distribution $\mathrm{P}(X|Y)$ on $\mathcal{X}$; or by drawing feature vector X from marginal distribution $\mathrm{P}(X)$ on $\mathcal{X}$ and then drawing a corresponding Y from conditional distribution $\mathrm{P}(Y|X)$ on $f(\mathcal{X})$.

★ *Page 10, Exercise 2.2*

After "… given losses $L(1,2) > 0$ and $L(2,1) > 0$" add "(assume $L(1,1) = L(2,2) = 0$)".

★★ *Page 19, Section 3.4 (Properties of Fitted Values)*

The first sentence should refer to Exercise 3.2, not Exercise 3.1.

★★ *Page 27, Section 3.9 (Feature Transformations, Expansions, and Interactions)*

In the second displayed equation, the limits on the double sum should be $\sum_{j=1}^{m-1} \sum_{k=j+1}^{m}$.

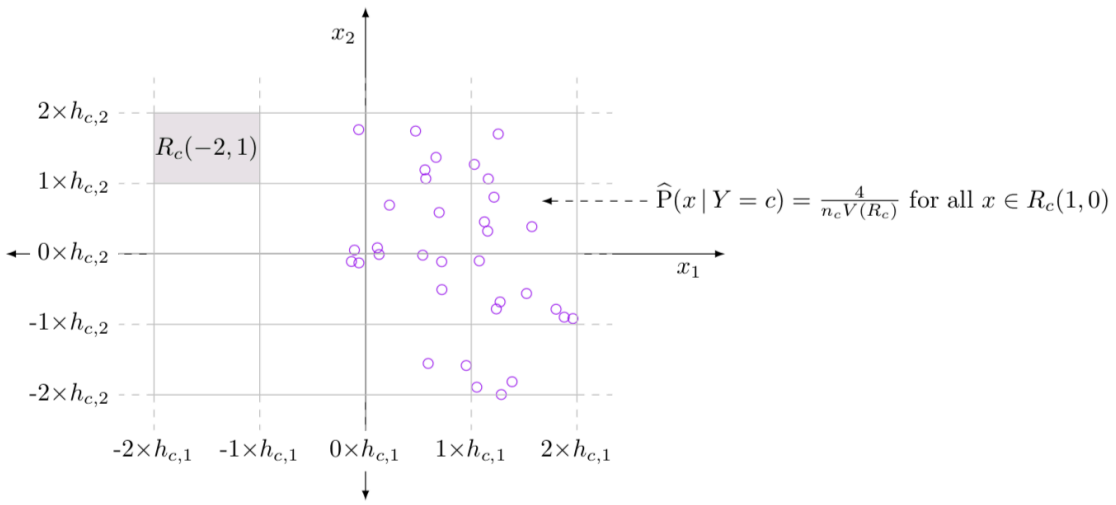
★★★ *Page 51, Section 4.4.5 (Histograms), first paragraph*

The histogram density estimate is

$$\widehat{\mathrm{P}}(x|Y=c) = \frac{n_c^{R_c(x)}}{n_c} \frac{1}{V(R_c)},$$

where $V(R_c) = h_{c,1} \cdots h_{c,m}$ is the volume of the rectangular cells for class *c*. This situation is illustrated in Figure 4.9.

★★★ *Page 52, Section 4.4.5 (Histograms), Figure 4.9*



★★★ *Page 54, Section 4.4.5 (Histograms), Exercise 4.8*

The last two displayed equations should be

$$\text{argmin}_{c=1,\ldots,C} \sum_{d=1}^{C} \mathrm{L}(d,c)\ \frac{n_d^{R_d(x)}}{V(R_d)}$$

and

$$\text{argmax}_{c=1,\ldots,C}\ \frac{n_c^{R_c(x)}}{V(R_c)}\ .$$

★★ *Page 60, Section 4.6 (Logistic Regression)*

In the second displayed equation on page 60, the vector θ is

$$\begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \vdots \\ \theta_C \end{bmatrix}$$

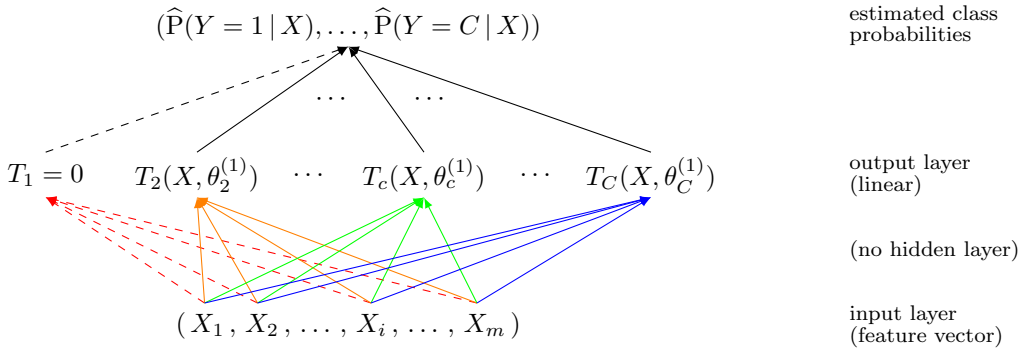
★★ *Page 61, Section 4.6 (Logistic Regression)*

The second sentence on page 61 should has some inconsistent subscripts. It should read: "The training data are assumed to be independent, which means that the class label Y_i is a single draw from the multinomial distribution with probability parameter $\mathrm{P}(Y|X = x_i)$,

$$Y_i|X_i = x_i \ \sim\ \text{Multinomial}\Big(1, \big(\mathrm{P}(Y = 1|X = x_i), \ldots, \mathrm{P}(Y = C|X = x_i)\big)\Big)\ .$$

★ *Page 73, Section 4.7.4 (Logistic Regression and Neural Networks), Figure 4.21*

In a perfect world, the labels at right would be consistent with those in Figure 4.17.



★★ *Page 84, Section 4.9.1 (Support Vector Machine Classifiers), second paragraph*

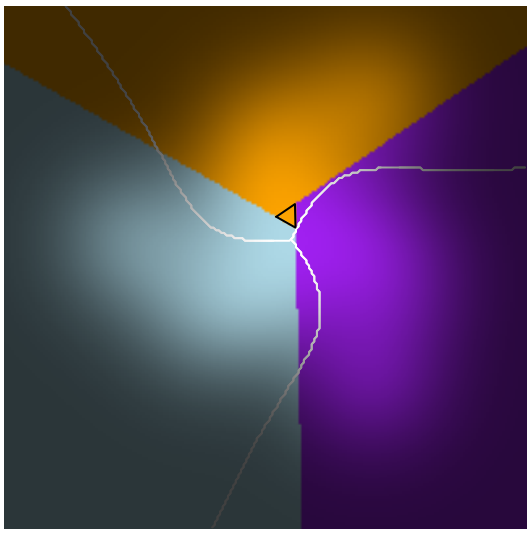
$\hat{\theta}_\star = \sum_{i:(x_i,y_i)\text{is a support vector}} \hat{\psi}_i\, y_i\, x_i$.

★ *Page 86, Section 4.9.1 (Support Vector Machine Classifiers), first paragraph*

In the second-to-last sentence, starting "As the distance from correctly classified data…", this sentence should be consistently either about data (plural) or a datum (singular).

★ *Page 88, Section 4.9.1 (Support Vector Machine Classifiers), Figure 4.30*

The picture would show what's going on more clearly with a small triangle added as shown:



The following should be appended to the caption: "The black triangle in the right-hand cell encloses a region in feature space where the orange-vs-blue SVM predicts orange, the orange-vs-purple SVM predicts purple, and the blue-vs-purple SVM predicts blue. The R function `svm()` has chosen (arbitrarily) to predict orange here."

★★ *Page 93, Section 4.10 (Postscript: Example Problem Revisited)*
On the fifth line from the bottom of the page, the text should read "those with risk 0.212 or below".

★★★ *Page 99, Section 5.1 (Squared-Error Loss), Figure 5.1 caption, first sentence*
The number 15 should be changed to 17.

★★★ *Page 99, Section 5.1 (Squared-Error Loss)*
The one paragraph on this page should read as follows:

"The bias and variance of three different methods of approximating function $f(x) = \frac{3}{4}x + \sin(\pi x)$ on the interval [-1,1] are illustrated in Figure 5.1. In the examples illustrated, n one-dimensional feature vectors $X_1, \ldots, X_n$ are drawn uniformly from [-1,1], and unioned with feature vectors $X_{n+1} = -1$ and $X_{n+2} = 1$. Then, for $i = 1, \ldots, n+2$, response $Y_i|X_i$ is drawn from a Gaussian distribution with mean $f(X_i)$ and unit variance (so the intrinsic risk with respect to squared-error loss is 1).

★★★ *Page 100, Section 5.1 (Squared-Error Loss), first paragraph and footnote 2*
The number 15 should be changed to 17 in the three places it occurs.

★★★ *Page 100, Section 5.1 (Squared-Error Loss), fifth paragraph*
The phrase "For each data size $|S| \in \{15,150,1500,15000,150000\}$" should read "For each data size $|S| \in \{15,150,1500,15000,150000\} + 2$".

★★★ *Page 101, Section 5.1 (Squared-Error Loss), Table 5.1 caption*
The number 15 should be changed to 17.

★★★ *Page 101, Section 5.1 (Squared-Error Loss), Table 5.1*
Each number in the left-hand column should have "+2" after it. For example, the first three numbers in the left-hand column should be "15+2", "150+2", and "1500+2". Additionally, Table 5.1 would be easier to read if horizontal lines separated it into three blocks: one where the values

of Degree (second column) are all 0, one where the values are all 3, and one where the values are all 6.

★ *Page 109, Section 6.1 (Ensembles), Figure 6.2 caption*

The following should be appended to the caption: "As noted in Figure 4.30, the R function `svm()` has chosen (arbitrarily) to break ties by predicting orange."

★ *Page 112, Section 6.3 (Bagging)*

The second sentence should have the phrase ", independently and uniformly" appended, reading: "A *bootstrap sample* of a dataset of size *n* is obtained by sampling the set with replacement *n* times, independently and uniformly."

★ *Page 112, Section 6.3 (Bagging), Exercise 6.3*

The second sentence should have the phrase "and uniformly" inserted, beginning: "Show that if a dataset of size *n* is sampled independently and uniformly with replacement […]."

★ *Page 112, Section 6.3 (Bagging), Exercise 6.3*

The phrase "a given bootstrap sample is about" should read "a given bootstrap sample ($\rho = 1$) is about".

★★ *Page 113, Section 6.3 (Bagging), Figure 6.3*

The risk of the 1-nearest neighbor classifier is 0.248, not 0.247.

★★ *Page 116, Section 6.5 (Random Forests)*

In the first sentence, "combination earlier" should be "combination of earlier".

★ *Page 117, Section 6.3 (Random Forests), Exercise 6.5, third paragraph, first sentence*

"Breiman defined the *random forest proximity* of two data points (x_i, y_i) and (x_j, y_j) to be the proportion of trees in a random forest with the property that (x_i, y_i) and (x_j, y_j) are in the same terminal node (leaf)."

★ *Page 119, Section 6.6 (Boosting), caption to Figure 6.7, second sentence*

It would have been more helpful if the second sentence read "Modifications for the case $C > 2$ and a reason for the particular choice of weight $\frac{1-\widehat{R_l}}{\widehat{R_l}}$ are described in the text and exercises."

★★ *Page 130, Section 7.2.3 (Size of Training, Validation, and Test Sets), first paragraph*

The phrase "The answer depends balancing" should be "The answer depends on balancing".

★★ *Page 131, Section 7.2.4 (Exercise 7.6 part (A))*

The parenthetical comment should have the word "to" added between the words "test" and "have", reading: "(this is what it means for the test to have level α – see Chapter 12)."

★★ *Page 134, Section 7.3 (Cross-Validation)*

The reference to Exercise 7.2 should have been a reference to Exercise 7.3.

★★★ *Page 138, Section 7.6 (Akaike's Information Criterion)*

In the first paragraph, the following sentence should be inserted before the last sentence: "AIC decreases the better the model fits the observed data, and increases the more complex the model is, where complexity is measured by the number of parameters, *k*."

The second paragraph should be replaced by the following:

"Akaike's criterion is an extension of the maximum likelihood principle. Suppose there are L models under consideration, $M_1, \ldots, M_L$, and that model M_i has a vector parameter θ_i of dimension k_i, and let $\hat{\theta}_i$ denote an estimate of θ_i derived in some way from a dataset $S = \{(X_1, Y_1), \ldots, (X_n, Y_n)\}$. The *maximum likelihood principle* states that, given observed data $(x_1, y_1), \ldots, (x_n, y_n)$, the "best" choice of model M_i and corresponding parameter θ_i is the one that maximizes the likelihood of the observed responses or classes,

$$\text{argmax}_{(M_1,\theta_1),\ldots,(M_L,\theta_L)} \text{P}(y_1, \ldots, y_n | x_1, \ldots, x_n, \theta_i, M_i).$$

Note that the maximization is taken over all models M_i and all possible parameters θ_i for each model M_i. Exercise 7.1 indicates a potential problem when using the maximum likelihood

principle for model selection. In contrast to the maximum likelihood principle, Akaike (1973) begins with the idea that the "best" choice of model M_i is the one that maximizes the expected log-likelihood of a response or class which has not yet been observed,

$$\text{argmax}_{M_1,\ldots,M_L} \mathrm{E}_{S,X,Y}\left[\log \mathrm{P}\left(Y \middle| X, \hat{\theta}_i, M_i\right)\right],$$

where the parameter estimate $\hat{\theta}_i$ for model M_i is estimated from the data set S. Akaike shows that, for large n, the model which maximizes the expected log-likelihood is approximately the model which maximizes the formula for AIC given at the start of this section. In the case of regression with additive, Gaussian-distributed noise, the expected log-likelihood is

$$\mathrm{E}_{S,X,Y}\left[\log \mathrm{P}\left(Y \middle| X, \hat{\theta}_i, M_i\right)\right] = -\frac{1}{2}\log(2\pi\sigma^2) - \frac{1}{2\sigma^2}\mathrm{E}_{S,X,Y}\left[\left(\mathrm{Y} - (1, \mathrm{X})\hat{\theta}_i\right)^2\right],$$

so selecting the model which maximizes the expected log-likelihood is equivalent to selecting the model which minimizes risk with respect to squared-error loss (see Section 3.6). In the case of classification by logistic regression and some neural networks, selecting the model which maximizes the expected log-likelihood is equivalent to selecting the model which minimizes risk with respect to cross-entropy loss (Sections 4.6 and 4.7, Exercise 4.11)."

★★★ *Page 139, Section 7.7 (Schwartz's Bayesian Information Criterion)*
Immediately before the second displayed expression, the words "the logarithm of the integral above" should be "the logarithm of the expression above".

★★ *Page 140, Section 7.8 (Rissanen's Minimum Description Length Crit.), second paragraph*
The phrase "observed features $x_1, \ldots, x_n$" should be "observed feature vectors $x_1, \ldots, x_n$".

★ *Page 140, Section 7.8 (Rissanen's Minimum Description Length Crit.), 2nd and 3rd paragraphs*
The references to Rissanen (1978) should be to Rissanen (1978, 1983).

★★ *Page 140, Section 7.9 (R^2 and Adjusted R^2)*
In the two displayed equations on this page, the expression "$n \times$" should appear immediately before $\widehat{\mathrm{R}}_{\text{train}}(\hat{f})$.

★ *Page 141, Section 7.9 (R^2 and Adjusted R^2)*
In the first displayed equation on this page, it would add to notational consistency to write

$$\text{MSS} = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2 = \sum_{i=1}^{n} (\hat{f}(x_i) - \bar{y})^2 .$$

★★ *Page 141, Section 7.9 (R^2 and Adjusted R^2), last paragraph, 2nd sentence*
"After all, RSS is a decreasing function of the training error" should be "After all, RSS is n times $\widehat{\mathrm{R}}_{\text{train}}(\hat{f})$".

★★ *Page 142, Section 7.10 (Stepside Model Selection), Figure 7.2*
In step (5), the subscript should refer to steps (3) and (4), not steps (2) and (3).

★ *Page 159, Chapter 10 introduction, second paragraph*
The phrase "Chapters 4 and 9" should be "Chapters 3, 4, 6, and 9".

★ *Page 172, Section 10.6.3 (Optimization from Multiple Starting Points)*
The author should have included the following paragraph as a second paragraph to this section. "It is also good practice, when an optimization algorithm converges to an approximate minimizer $\omega^\star$, to restart the algorithm at $\omega^\star$. Either the algorithm does not find a better minimizer than $\omega^\star$, in which case it typically declares convergence at $\omega^\star$ after little work, relative to the work performed to find $\omega^\star$ in the first place; or it does find a better minimizer than $\omega^\star$."

★ *Page 217, Introduction to Chapter 12, first paragraph*
In the first sentence, the first "the" should be omitted from "in the one or more of the".

★★ *Page 220, Section 12.2 (Terminology for Binary Decisions), Table 12.2*
In the right most column, the entry "risk" should be changed to "risk (under 0-1 loss)".

★ *Page 226, Section 12.6.1 (Control the Familywise Error), first paragraph*

The first sentence would be clearer if a mathematical expression for the familywise error rate were given.

"The *familywise error rate* of T statistical tests is the probability that *any* of the tests incorrectly rejects the null hypothesis,

$$\mathrm{P}\left(\bigcup_{i=1}^{T}\{H_0 \text{ is true for the } i\text{th test and the } i\text{th test rejects } H_0\}\right)."$$

To make the texts parallel, then, in *Page 227, Section 12.6.2 (Control the False Discovery Rate), first paragraph*, the first sentence should be rewritten as follows.

"The *false discovery rate* of T statistical tests is probability that the null hypothesis is true for a test, conditional on that test rejecting the null hypothesis,

$$\mathrm{P}(H_0 \text{ is true} | H_0 \text{ is rejected})."$$

★ *Page 228, Section 12.7 (Expert Systems)*

The final statement by Client should have closing quotation marks.

★★★ *Page 249, Section 14.9 (Histograms), third paragraph*

The line

`HT$iv` --- a vector $(V(R_1)^{-1}, \ldots, V(R_C)^{-1})$ of reciprocals of cell volumes;

should be added between the lines

`HT$h` --- the $C \times m$ matrix of bandwidth parameters, h;

and

`HT$prior` --- the marginal distribution of class labels which occur in the training data.

★★★ *Page 250, Section 14.9 (Histograms), function hist.insert()*

The two lines

```
if(has.key(key,HT[[daty]])==FALSE) { HT[[daty]][key]=1; }
else { HT[[daty]][key]=values(HT[[daty]][key])+1; }
```

should be replaced with the two lines

```
if(has.key(key,HT[[daty]])==FALSE) { HT[[daty]][key]=HT$iv[daty]; }
else { HT[[daty]][key]=values(HT[[daty]][key])+HT$iv[daty]; }
```

★★★ *Page 250, Section 14.9 (Histograms), function hist.train()*

The line

```
HT$iv <<- 1/apply(HT$h,1,prod);
```

should be inserted between the line

```
for(cc in 1:nc) { HT[[cc]] <<-hash(); };
```

and the line

```
apply(cbind(datx,daty),1,hist.insert);
```

★★ *Page 264, Section 14.15 (Classification Trees)*

The word "tree" should be inserted in the phrase "The estimated risk $\widehat{\mathrm{R}}_0$ of the one-leaf can be computed", resulting in "The estimated risk $\widehat{\mathrm{R}}_0$ of the one-leaf tree can be computed".

★★ *Page 287, Solution to Exercise 6.1*

The following should be inserted before the last sentence of the solution. "Since risk R grows without bound as any c_l goes to ∞, R has no maximum. Since $\mathrm{R} \geq \beta$, R has a minimum, and the critical point is the minimum."

★★ *Page 289, Solution to Exercise 7.1*

The one inequality symbol in the solution should be reversed: the statement $\widehat{\mathrm{R}}_{\mathrm{valid}}(\hat{f}_{d+1}) \geq \widehat{\mathrm{R}}_{\mathrm{valid}}(\hat{f}_d)$ should be $\widehat{\mathrm{R}}_{\mathrm{valid}}(\hat{f}_{d+1}) \leq \widehat{\mathrm{R}}_{\mathrm{valid}}(\hat{f}_d)$.

★★ *Page 311, References*

Rissanen's 1978 paper is in *Automatica* volume 14, not volume 15. Also, I should add the following reference, which is the source of the key ideas presented in Section 7.8 (Minimum Description Length):

Rissanen, J. (1983). A Universal Prior for Integers and Estimation by Minimum Description Length. *The Annals of Statistics*, 11(2), 416-431.

★★ *Solution to Exercise 3.4 (web solutions)*

In the following equation, the expectation shown in red is missing and should be added:

$$\mathrm{E}[\hat{\mathbf{e}}] = \mathrm{E}[\mathbf{y} - \hat{\mathbf{y}}] = \mathrm{E}[\mathbf{y}] - \mathrm{E}[\hat{\mathbf{y}}]$$

★★★ *Solution to Exercise 4.8 (web solutions)*

Exercise 4.8 *The histogram classifier predicts*

$$\mathrm{argmin}_{c=1,\ldots,C} \sum_{d=1}^{C} L(d,c)\, \widehat{\mathrm{P}}(x|Y=d)\mathrm{P}(Y=d) =$$

$$\mathrm{argmin}_{c=1,\ldots,C} \sum_{d=1}^{C} L(d,c) \frac{n_d^{R_d(x)}}{n_d} \frac{1}{V(R_d)} \frac{n_d}{n} = \mathrm{argmin}_{c=1,\ldots,C} \sum_{d=1}^{C} L(d,c) \frac{n_d^{R_d(x)}}{V(R_d)}$$

Under 0-1 loss, minimizing the sum of losses means maximizing the term left out, so the predicted class is

$$\mathrm{argmax}_{c=1,\ldots,C} \frac{n_c^{R_c(x)}}{V(R_c)}.$$

★ *Solution to Exercise 7.4 (web solutions)*

The prime notation can be removed from the letter μ where it occurs in the first sentence (μ' is replaced by μ).