

# Task 1.2. Supervised Learning: Bayesian Linear Regressor

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## 1 Introduction

Simple linear regressors are overconfident in their predictions. Bayesian linear regressors are an extension of this model used to solve this particular issue.

## 2 The problem

In this model we want to compute a posterior distribution given a set of training samples, as shown in Equation 1. Where  $\mathbf{w}$  is a one dimensional array with the world state,  $\mathbf{X}$  is a matrix with the data points,  $\phi$  are the parameters of a linear function of the data.

$$Pr(\phi|\mathbf{X}, \mathbf{w}) = \frac{Pr(\mathbf{w}|\mathbf{X}, \phi)Pr(\phi)}{Pr(\mathbf{w}|\mathbf{X})} \quad (1)$$

The prior in Equation 1 is a normal distribution with 0 mean and spherical covariance. And the likelihood is a multivariate normal distribution, as shown in Equation 2. Where  $\sigma^2$  is the covariance,  $\mathbf{I}$  is the identity matrix and  $\boldsymbol{\theta} = \{\phi, \sigma^2\}$ .

$$Pr(\mathbf{w}|\mathbf{X}, \boldsymbol{\theta}) = Norm_{\mathbf{w}} [\mathbf{X}^T \phi, \sigma^2 \mathbf{I}] , \quad (2)$$

The posterior distribution is shown in Equation 3.

$$Pr(\phi|\mathbf{X}, \mathbf{w}) = Norm_{\phi} \left[ \frac{1}{\sigma^2} \mathbf{A}^{-1} \mathbf{X} \mathbf{w}, \mathbf{A}^{-1} \right] , \quad (3)$$
$$\mathbf{A} = \frac{1}{\sigma^2} \mathbf{X} \mathbf{X}^T + \frac{1}{\sigma_p^2} \mathbf{I},$$

The probability distribution of a new world state  $w^*$  over new test data  $x^*$  is a Normal distribution as shown in Equation 4.

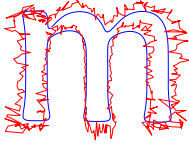
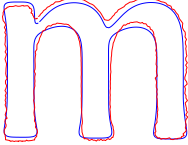
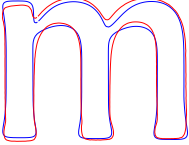
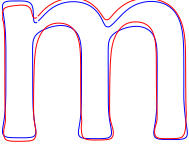
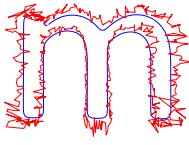
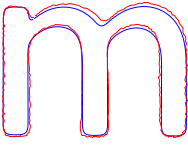
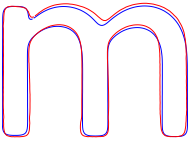
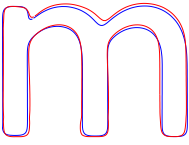
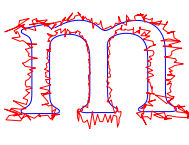
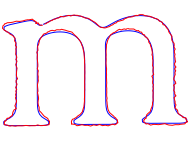
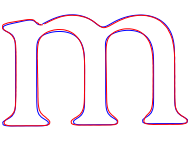
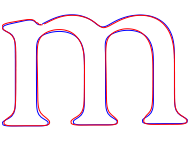
$$\begin{aligned}
Pr(w^*|\mathbf{x}^*, \mathbf{X}, \mathbf{w}) &= \int Pr(w^*|\mathbf{x}^*, \phi) Pr(\phi|\mathbf{X}, \mathbf{w}) d\phi, \\
&= Norm_{w^*} \left[ \frac{1}{\sigma^2} \mathbf{x}^{*T} \mathbf{A}^{-1} \mathbf{X} \mathbf{w}, \mathbf{x}^{*T} \mathbf{A}^{-1} \mathbf{x}^* + \sigma^2 \right],
\end{aligned} \tag{4}$$

Since our world states  $\mathbf{w}_i$  are multivariate, a separate regressor is used for each dimension in  $\mathbf{w}_i$ .

### 3 Results

In Table 1 we show results for a font data set. The Bayesian linear regressors is trained with pictures of  $n$  in different fonts and their corresponding  $m$  in the same font. For testing,  $n$  with new fonts are used.

Table 1: Comparing the reconstruction of several  $m$  with different fonts and variances. In blue is the ground truth and in red is the reconstructed character.

	$\sigma^2 = 10$	$\sigma^2 = 1$	$\sigma^2 = 0.01$	$\sigma^2 = 0.001$
Font1				
Font2				
Font3				

As the Table 1 shows smaller variances  $\sigma^2$  produce better results. Therefore, we can conclude that our Prior model of a Normal distribution is a appropriate choice for this data set. Furthermore, looking at the covariance we can see how confident the prediction.