

Chapter 13

The Multivariate Gaussian

In this chapter we present some basic facts regarding the multivariate Gaussian distribution. We discuss the two major parameterizations of the multivariate Gaussian: the centered parameterization and the canonical parameterization, and we show how the basic operations of marginalization and conditioning are carried out in these two parameterizations. We also discuss maximum likelihood estimation for the multivariate Gaussian.

13.1 Parameterizations

The multivariate Gaussian distribution is conventionally expressed in terms of the parameters μ and Σ , where μ is an $n \times 1$ vector and Σ is an $n \times n$ symmetric matrix. (We will assume for now that Σ is also positive definite, but later we will have occasion to relax this constraint). We have the following form for the density function:

$$p(\mathbf{x}|\mu, \Sigma) = \frac{1}{(2\pi)^{n/2} |\Sigma|^{1/2}} \exp\left\{-\frac{1}{2}(\mathbf{x} - \mu)^T \Sigma^{-1}(\mathbf{x} - \mu)\right\}, \quad (13.1)$$

where \mathbf{x} is a vector in \mathbb{R}^n . The density can be integrated over values in \mathbb{R}^n to verify probabilistic axioms for these values.

The geometry of the multivariate Gaussian is essentially that associated with the quadratic form $f(\mathbf{x}) = \frac{1}{2}(\mathbf{x} - \mu)^T \Sigma^{-1}(\mathbf{x} - \mu)$ in the exponent of the density. Recall our discussion in Chapter 11, where we showed that a quadratic form $f(\mathbf{x})$ is a paraboloid with level surfaces, i.e., surfaces of the form $f(\mathbf{x}) = c$ for fixed c , being ellipsoids centered along the eigenvectors of the matrix Σ . Note that the eigenvectors, $\text{eig}(\Sigma)$, is a vector function that spans the generalized moments of the quadratic form system. Thus in the case c being an eigenvalue $f(\mathbf{x}) = c$, we obtain the (open) set $\{\cdot, \cdot\}$. The maximum value of the exponent is 0, obtained at $\mathbf{x} = \mu$ where $f(\mathbf{x}) = 0$. The paraboloid $f(\mathbf{x})$ increases to infinity as we move away from $\mathbf{x} = \mu$, thus we obtain a “bowl” in $(n - 1)$ -dimensional space centered at $\mathbf{x} = \mu$. The level surfaces of the Gaussian being an ellipsoid centered along the eigenvectors of Σ .

Chapter 13 The Multivariate Gaussian People

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