

<<偏微分方程数值解的有效条件数>>

图书基本信息

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章节摘录

Chapter 1 Effective Condition Number In this beginning chapter, new computational formulas are provided for the effective condition number $\text{Cond } e^?$, and new error bounds involved in both Cond and $\text{Cond } e^?$ are derived. A theoretical analysis is provided to support some conclusions in Banoczi et al. [14]. For the linear algebraic equations solved by Gaussian elimination (GE) or the QR factorization (QR), the direction of the right-hand vector is insignificant for the solution errors, but such a conclusion is invalid for the finite difference method for Poisson's equation. The effective condition number is important to the numerical partial differential equations, because the discretization errors are dominant. The materials of this chapter are adapted from [95, 127, 134, 138, 218].

1.1 Introduction The definition of the traditional condition number was given in Wilkinson [227], and then used in many books and papers. To solve the overdetermined system of the linear algebraic equations $Fx = b$, the traditional condition number in the 2-norm is defined by $\text{Cond} = \frac{\sigma_1}{\sigma_n}$, where σ_1 and σ_n are the maximal and the minimal singular values of matrix F , respectively. The condition number is used to provide the bounds of the solution errors from the perturbation of both matrix F and vector b . The new computational formulas are derived in this chapter for the effective condition numbers, denoted by $\text{Cond } e^?$, $\text{Cond } E$ and $\text{Cond } EE$. The $\text{Cond } e^?$ denotes the enlarged factor of the solution errors over the residual errors. For further application, in this chapter we also derive the new error bound involved in both Cond and $\text{Cond } e^?$. In this new bound, the Cond and the $\text{Cond } e^?$ denote basically the enlarged factors of the errors over the perturbation errors of matrix F and vector b , respectively. Hence, when the matrix and the vector errors are dominant, Cond and $\text{Cond } e^?$ will play an important role, respectively. First, we apply $\text{Cond } e^?$ to the linear algebraic equations, and a theoretical justification is given to support some conclusions in [14]. For the solution errors of the algebraic equations by Gaussian elimination (GE) or the QR factorization (QR), the direction of the right-hand vector is insignificant. Then we apply $\text{Cond } e^?$ to the numerical partial differential equations (PDE) and the Trefftz method (TM) for Poisson's equation. Since the discretization errors are dominant, the effective condition number is important. Moreover, since the TM solution is highly accurate, the small effective condition number well explains the high accuracy of the solutions, and strengthens the collocation Trefftz method (CTM) in [155], where only error bounds and numerical experiments are provided without the stability analysis. It is explored in this chapter and the entire book that the huge Cond is often misleading, but the effective condition number is the appropriate criterion for the stability analysis. Here let us illustrate the references of the condition number and the effective condition number. The traditional condition number Cond was first given in Wilkinson [227], and then used in many textbooks, such as Strang [197], Atkinson [3], Schwarz [191], Datta [44], Gill et al. [65], Golub and van Loan [66], Stewart [195], Horn and Johnson [90], Sun [199], Wang et al. [212], and Higham [88]. The condition number for eigenvalues is introduced in Parlett [180] and Frayssé and Toumazou [61], and there are more discussions in Gulliksson and Wedin [71], and Elsner et al. [55]. The Cond is applied to the numerical partial differential equations in Strang and Fix [198], Quarteroni and Valli [184] and Li [115]. On the other hand, the effective condition number was defined and studied in Chan and Foulser [27]. However, its algorithm was first proposed in Rice [186] in 1981, but the natural condition number was called. Only a few reports, such as Christiansen and Hansen [37], Christiansen and Saranen [38], Banoczi et al. [14], and Axelsson and Kaporin [7, 8], follow the line of the effective condition number. The error estimates for the solution of the linear algebraic system in Brezinski [20] are also related to the effective condition number. Recently, the new computational formulas of effective condition number have been studied and applied to symmetric and positive definite matrices, which are obtained from Poisson's equation by the finite difference method (FDM) in [127].

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