On Tikhonov's Method for Ill-Posed Problems*

By Joel N. Franklin

Abstract. For Tikhonov's regularization of ill-posed linear integral equations, numerical accuracy is estimated by a modulus of convergence, for which upper and lower bounds are obtained. Applications are made to the backward heat equation, to harmonic continuation, and to numerical differentiation.

1. **Introduction.** Tikhonov's method applies to the integral equation

$$(1.1) \qquad \int_0^1 k(x, y)u_0(y)dy = g_0(x) \quad (0 \leq x \leq 1).$$

The problem is to find u_0 if k and g_0 are known.

This problem is ill-posed if k is any measurable kernel. That follows from Riemann's lemma:

$$(1.2) \qquad \int_0^1 k(x, y) \sin \lambda y \, dy \longrightarrow 0 \quad \text{as} \quad \lambda \longrightarrow \infty$$

which shows that a small change in the data, δg_0, may correspond to a large change in the answer, δu_0: for some large λ, let $\delta g_0(x)$ equal the integral (1.2); this is a small data-change corresponding to the large answer-change $\delta u_0(y) = \sin \lambda y$.

Many ill-posed problems can be stated as integral equations. In this paper, we will discuss three ill-posed problems: the *backward heat equation, harmonic continuation,* and *differentiation.* All will be stated as integral equations. To each, we will apply Tikhonov's method, and we will find the *rate of convergence.* The rate of convergence gives an estimate of the accuracy of the computed solution.

2. **Tikhonov's Method.** We suppose that $u_0(y)$ solves the integral equation (1.1). The kernel $k(x, y)$ is known, and a function $g(x)$ is known such that

$$(2.1) \qquad \|g - g_0\| \leq \epsilon.$$

We will use the notation $\|\varphi\|$ to mean the L_2-norm:

$$\|\varphi\| = \left(\int_0^1 \varphi^2(x)dx \right)^{1/2}$$

The assumption (2.1) is used instead of $g = g_0$ because, in practical applications, the

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Ling Xin,Bin Zhou,Haitao Lin,Arindam Dey

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