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FORMULATION OF LOCAL AND NON-LOCAL BOUNDARY PROBLEMS FOR HYPERBOLT EQUATIONS

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Annotation: In this paper, we study the formulation of local and nonlocal boundary value problems for hyperbolic equations.

Keywords: initial condition, boundary condition, differential equation, string, function, domain.

When describing a physical process mathematically, one must first pose a problem, i.e. formulate conditions sufficient for an unambiguous definition of the process.

Differential equations with ordinary and especially with partial derivatives have, generally speaking, an infinite number of solutions. Therefore, in the case when a physical problem is reduced to an equation with partial derivatives, in order to unambiguously characterize the process it is necessary to add some additional conditions to the equation.

Let's consider the simplest problem of transverse vibrations of a string fixed at the ends. In this problem, it gives the deviation of the string from the axis. If the ends $0 \le x \le l$ of the string are fixed, then the "boundary conditions" must be satisfied

$$u(0,t)=0, \quad u(l,t)=0.$$

Since the process of oscillation of the string depends on its initial shape and velocity distribution, the initial "initial conditions" should be set:

$$\left.\begin{array}{l} u(x,t_0)=\varphi(x), \\ u_t(x,t_0)=\psi(x). \end{array}\right\}$$

Thus, additional conditions consist of boundary and initial conditions, where $\varphi(x)$ and $\psi(x) -$given point functions.

Let us now turn to the consideration of limiting cases of the problem posed. The influence of boundary conditions at a point M_0, sufficiently distant from the boundary at which they are specified is felt after a sufficiently large period of time.

If we are interested in a phenomenon during a short period of time, when the influence of boundaries is still insignificant, then instead of the complete problem we can consider a limit problem with initial conditions for an unlimited area:

find a solution to the equation

$$u_{tt}=a^2u_{xx}+f(x,t) \text{ для } -\infty<x<\infty, \quad t>0,$$

with initial conditions

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$$\left.\begin{aligned} u(x,0) &= \varphi(x), \\ u_t(x,0) &= \psi(x) \end{aligned}\right\} \quad \text{at } -\infty < x < \infty.$$

This problem is often called the Cauchy problem.

If we study a phenomenon near one boundary and the influence of the boundary regime on the second boundary is not significant during the period of time of interest to us, then we come to the formulation of the problem on a semi-bounded straight line when, in addition to the equation, additional conditions are given:

$$\left.\begin{aligned} u(0,t) &= \mu(t), \\ u(x,0) &= \varphi(x) \\ u_t(x,0) &= \psi(x) \end{aligned}\right\} \qquad \left.\begin{aligned} t &\geq 0, \\ 0 \leq x &< \infty. \end{aligned}\right\}$$

The nature of the phenomenon for moments of time sufficiently distant from the initial moment $t = 0$, is completely determined by the boundary values, since the influence of the initial conditions, due to the friction inherent in any real system, weakens over time. Problems of this type occur especially often in cases where the system is excited by a periodic boundary mode that operates for a long time. Such problems "without initial conditions" are formulated as follows:

find a solution to the equation under study for $0 \leq x \leq l$ at $t > -\infty$ under boundary conditions

$$\left.\begin{aligned} u(0,t) &= \mu_1(t), \\ u(l,t) &= \mu_2(t). \end{aligned}\right\}$$

The problem without initial conditions for a semi-bounded line is posed similarly.

If the solution to a mathematical problem continuously depends on additional conditions (on the initial, boundary data and on the right side of the equations - on the initial data of the problem), then the problem is stable.

In the theory of differential equations, initial and boundary conditions are additions to the main differential equation (ordinary or partial differential), specifying its behavior at the initial moment of time or at the boundary of the region under consideration, respectively.

Usually a differential equation has not one solution, but a whole family of them. Initial and boundary conditions allow you to select one from it that corresponds to a real physical process or phenomenon. In the theory of ordinary differential equations, a theorem on the existence and uniqueness of a solution to a problem with an initial condition (the so-called Cauchy problem) has been proven. For partial differential equations, some existence and uniqueness theorems for solutions for certain classes of initial and boundary value problems are obtained.

For some problems, there is a division of boundary conditions into main and natural ones. The main conditions usually take the form $u(\partial\Omega) = g$, where $\partial\Omega -$is the boundary of the region Ω. The natural conditions also contain the derivative of the solution along the normal to the boundary.

Problems of mathematical physics describe real physical processes, and therefore their formulation must satisfy the following natural requirements:

1. The solution must exist in some class of functions;
2. The solution must be unique in any class of functions;

3. The solution must continuously depend on the data (initial and boundary conditions, free term, coefficients, etc.).

In mathematical biology, as in mathematical physics, a distinction is made between correctly and incorrectly posed problems. The concept of a well-posed problem statement was introduced by J. Hadamard. The formulation of problems contains some initial data included in the boundary, internal or internal boundary conditions, and, as a rule, the sought solution depends on these data. Initial data (or input data) are usually determined from experience and therefore cannot be found absolutely accurately. It is always inevitable that there will be some error in the input data, such as initial or boundary data. This error, even if small, will obviously affect the solution, and the error in the decision will not always turn out to be small.

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