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A NEW COMPUTATIONAL METHOD FOR OPTIMIZING NONLINEAR IMPULSIVE SYSTEMS

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Abstract. In this paper, we consider a system that evolves by switching between several subsystems of ordinary differential equations. The switching mechanism in this system induces an instantaneous change in the system's state, which can be controlled through a set of decision parameters. We develop a new computational method, based on nonlinear programming, for optimizing the system parameters and the subsystem switching times. We then successfully apply this method to two interesting examples.

Keywords. Nonlinear optimal control, Impulsive system, Gradient-based optimization, Nonlinear programming, Time-scaling transformation.

AMS (MOS) subject classification: 49J15, 49N25, 90C30.

1 Introduction

Many real-life systems operate by switching between different subsystems or modes. Such systems are called *switched systems*. An example of a switched system is a switched-capacitor DC-DC power converter, which operates by periodically changing its circuit topology [6,14]. Other examples of switched systems include robots [2], locomotives [7,8], hybrid power generators [19], and biochemical reactors [3,4].

In some switched systems, changing mode causes an instantaneous change in the system's state—a so-called *state jump*. For example, changing the circuit topology of a switched-capacitor DC-DC power converter causes a sudden voltage drop in the power converter's capacitors. Switched systems of this type, in which subsystem switches are accompanied by state jumps, are called *impulsive systems*.

In this paper, we consider an impulsive system whose subsystems are described by nonlinear ordinary differential equations. The state jumps in this system can be controlled through a set of system parameters. Our goal is to choose values for these system parameters and the subsystem switching times to minimize a given cost function.

This type of dynamic optimization problem is a major computational challenge. There are two reasons for this: