Abstract

This thesis work presents control designs in presence of non-differentiability and uncertainty in systems using fractional-order sliding mode control. The work can be divided into two main parts. The first part deals with the non-differentiability issues in control problems. In this context, two problems are considered which are the tracking problem and differentiator design problem. The issues occuring due to non-differentiability of some functions in these two problems are highlighted. A solution to the problems is proposed by using fractional-order operators. It is shown how these operators relax the required differentiability condition on the functions in case of techniques involving integer-order operators. the second part discusses a sliding mode control based design for a class of uncertain fractional-order systems. The classical fractional-order sliding mode based design cannot guarantee robustness in the reaching phase. In order to ensure robustness throughout the evolution of the trajectories, a new approach is proposed which is free from the reaching phase. The states are on the sliding surface from the very beginning achieving the desired robustness throughout their evolution. These works are further detailed in the following.

The non-differentiability issue in the tracking problem is presented first in the second chapter. A precise problem formulation is provided and the constraint due to non-differentiability of the reference function is highlighted. It is proposed and demonstrated that the fractional-order operators can be used to resolve the non-differentiability issue. The proposed technique is further detailed by considering a case study of a switch-controlled RL circuit. Possible cases are elaborated and the condition required to be satisfied by the reference function is derived for each possible case of the error dynamics. Improvement in tracking is illustrated through simulation results. The generalized nature of the applicability of the proposed approach to general class of nonlinear systems is also shown.

The next chapter considers the problem of designing differentiators. A second-order super-twisting based sliding mode control is designed. It also involves fractional-order operators to alleviate the limitation of existing works that require the signal to be second-order dfferentiable. Further, suppression of the chattering is done by using implicit Euler discretization and Fractional Adams-Moulton method. The discretization of the associated equations is shown with a detailed derivation of the final equations of the discrete-time fractional-order differentiator. An example of a buck converter circuit is taken and simulation results are shown. A detailed discussion on the results with improved accuracy is provided.

Work in the fourth chapter considers the class of uncertain fractional-order systems. Sliding mode control design for such systems is carried out by using two sliding surface design approaches. The first approach is based on the integer reaching law and the second one discusses the fractional reaching law. Detailed derivations of the dynamic equations are given. The expressions of finite time are derived in each case. Next, a design scheme is presented which is free from any reaching phase. Thus, the trajectories evolve on the sliding surface from the very beginning. This ensures robustness throughout their evolution making the overall system robust with respect to uncertainties for all time. Finally, the technique is illustrated by an application on fractional inverted pendulum system. The technique is applied on its linearized model and simulation results are discussed.