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ScienceDirect

Procedia Computer Science 92 (2016) 589 – 594

Procedia Computer Science

2nd International Conference on Intelligent Computing, Communication & Convergence

(ICCC-2016)

Srikanta Patnaik, Editor in Chief

Conference Organized by Interscience Institute of Management and Technology

Bhubaneswar, Odisha, India

Pollen Rate Based Control and Stabilization of Double Inverted Pendulum

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Abstract

Naturally inspired Flower pollination unconstrained optimization method is applied for the stabilization of the double inverted pendulum control problem as part of this study which is a novelty. The optimization was applied under the influence of time delay and have proven that the influence of time delay is significantly felt and would cause loss of energy, however the presence of flower pollination for optimization minimizes the loss incurred due to time delay and makes the system significant in terms of sensitivity. The influence on settling time and peak overshoot are studied and are compared for performance with and without time delays. The developed strategy paves way to the analysis of complex dynamic systems wherein the controller design when designed using naturally inspired algorithm would make the system energy efficient.

Peer-review under responsibility of the Organizing Committee of ICCC 2016

*Keywords:*Flower Pollination, Time delay, Double Inverted pendulum

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doi:10.1016/j.procs.2016.07.387

1. Introduction

The control problem of the inverted pendulum dates back to the great Indian magicians who used to make a rope stand in thin air. The trick is the present day control problem of a broom stick balancing in the palm. The double inverted pendulum is an advanced version of the same trick only to show the world that it is something well beyond a normal control strategy because it is highly unstable, under-actuated in the sense that the number of inputs is less than the number of control variables. This control problem has been investigated by researchers across the globe by many people starting as a mathematical model by mathematicians to robotic designers. It could as well be generalized and said that the study of this pendulum system itself paves way to study of complex dynamic systems because it gives an overall image of the strategy to be developed when the trade off is between various constraints whose proportional weight in the trade off increases and decreases based on the user requirements. A good scenario is to look at the tradeoff between the settling time and the peak overshoots. Now, if the requirement is to smoothen the response then we could as well compromise on the peak overshoot. Else, if the voltage constraints are stringent, there could a rigid response and the emphasis lies on the peak overshoot.

Studies on time delays have been investigated in the context of dead time and unwanted time delays caused in cascaded systems due to inherent processing [1]. Though, it is to be considered that in the presence of time delay, the control effort can have minimal effect until the delay is passed and the control signal can only influence after the dead time has passed which by itself shows the important impact of time delay.

In the context of the impact of time delays and the studies of inverted pendulum, this paper is enriched with the ideology of time delay influence on double inverted pendulum where the time delay effect is mitigated by analysis using flower pollination(FP). Earlier work on similar aspects using a BAT algorithm in view of advantages is seen in [2]. Flower pollination is a nature inspired algorithm which has emphasis on a single objective unconstrained optimization[3]. The evolution of various flowering plants is an example by itself on indicating the efficiency of evolutionary process. Yang[4] has clearly developed and outlined the advantages based on how pollen gets transferred which becomes the approach for the development of the algorithm. The important advantage of the flower pollination algorithm beings its simplicity in implementation with two unique parameters.

The sensitivity of such a system when influenced by parameters like time delay with an optimization analysis done using flower pollination is not studied in literature. In view of the vivid advantages that have been outlined, this paper investigates the methods for control and stabilization of the double inverted pendulum using flower pollination which is a work which was not carried so far. It definitely paves way to new domains of research in the context of the analysis under the influence of time delays.

2. MATHEMATICAL MODELLING

2.1 System Dynamics with Time Delay

A typical arrangement of the double inverted pendulum dynamics involves Euler-Lagrangian equation as in [2]. The important system parameter state variables include X , Θ_1 and Θ_2 which denote the cart position, the lower pendulum angle with respect to the vertical , Θ_2 is the upper pendulum angle with respect to the pendulum and Θ_3 is the angle with respect to the vertical. F is the force acting on the cart. The output includes a integrated time delay parameter as defined by [1] . The seven states includes the cart position, velocity, lower pendulum position, velocity, upper pendulum velocity and position and the seventh state is the integrated time delay state.