

Communication Limited Stabilization of Linear Systems in the Presence of Uncertainty

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Abstract- *Communication is an important component of distributed and networked control systems. Because there is a need for understanding the interaction between the control and communication component. In this paper we will consider the control problem with communication channel connecting the sensor to the controller. The main task is to determine the minimum bit-rate necessary to stabilize a linear time-invariant system in the presence of uncertainty. When noise is absent, we will determine a bit-rate above which asymptotic stabilization can be achieved. Using ideas from differential pulse code modulation (DPCM) it is proposed encoding / decoding scheme that guarantee boundedness of the state in the presence of disturbance and unmodeled dynamics. It is formally shown that presence of unmodeled dynamics increase the lower bound of bit-rate which guarantee stability of the system.*

Keywords: *Communication, networked control, quantization, DPCM, bit-rate, stability*

I. INTRODUCTION

Communication and control, until recently, have been areas with little common elements. For the most part communication theory deal with reliable transmission of information from one point to another. On the other hand, control theory is concerned mainly with using information in a feedback loop to achieve some performance objective and assumes that limitation in the communication link are not significant enough for performance. But, in the distributed and networked control systems communication is very important component. Hence, there is a need to understand the relation between communication and control. In the close future the understanding control over communication networks is a major topic in the control fields [1]

In this paper we will consider the problem of stabilizing a linear systems with unmodeled dynamics, through feedback under constraints on the bit-rate of the feedback loop. The actuator and the sensor are connected through a communication channel with finite bandwidth. The problem of stabilization with finite communication bandwidth was introduced in [3]. The ideas further is developed in many papers. In [4] is proposed control design methodology which relies on the possibility of changing the sensitivity of the quantizer while the system evolves. Reference [5] describes the coarsest quantizer that quadratically stabilizes a single input linear discrete time invariant system. Quantizer is logarithmic and can be computed by solving a special linear quadratic regulator problem. Recently, the

stabilization method, based on the chaotic behaviour of piecewise affine maps is proposed [6]. In [7] is provided upper and lower bounds on the channel rate for different control objectives for which is defined information complexity. Also, exist a few monographs which are devoted to limited data rate in control systems with networks [8] and [9].

Result of this paper is close to results in the reference [10]. The main difference is introduction, in this paper, of unmodeled dynamics and different assumptions about the input disturbance. As far as we know, that is the first consideration of quantization problem in the presence of uncertainty in the form of unmodeled dynamic. In the first part of the paper we will find minimum bit-rate for which stabilization of noiseless process, in the presence of uncertainty, is possible. After that, in the second part of paper, we will consider the design of encoder/decoder pairs for linear systems with unmodeled dynamics and state can be measured by noisy sensors. In the area of communication it is well known differential pulse code modulation (DPCM) which employs a linear predictor so that the prediction error rather than the complete signal is quantized and sent to the receiver [11]. By quantizing an estimation error instead of the process state, it is possible to significantly reduce the bit-rate needed to stabilize the process. Both, encoder and decoder must to track the state of the system and, because, predictor is constructed using the reconstructed state data to estimate the expected state of the system of the next sampling time. In this paper the fixed step quantization is used. Also, one can to adopt the approach that it is possible to vary some parameters of the quantizer on line, on the basis of collected data. From the results of this paper follows that presence of uncertainty increases bit-rate which is need for system stability.

Very general approach for control of "difficult" systems is exploitation of hybrid controllers [12]. In [13] systems with quantization can be viewed as a hybrid systems. Namely, in the presence of quantization, the state space of the system is divided into a finite number of quantization regions, each corresponding to a fixed value of the quantizer. As the time of passage from one quantization region to another, the dynamics of the system change abruptly. Hybrid control system can be very useful for robust control [14] and time-delay system [15] where LMI tool is used.

