Modeling MPEG VBR Video Traffic Using Type-2 Fuzzy Logic Systems

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Abstract. In this chapter, we present a new approach for MPEG variable bit rate (VBR) video modeling using a type-2 fuzzy logic system (FLS). We demonstrate that a type-2 fuzzy membership function, i.e., a Gaussian MF with uncertain variance, is most appropriate to model the log-value of I/P/B frame sizes in MPEG VBR video. We treat the video traffic as a dynamic system, and use a type-2 FLS to model this system. Simulation results show that a type-2 FLS performs much better than a type-1 FLS in video traffic modeling.

1 Introduction

Multimedia technologies will profoundly change the way we access information, conduct business, communicate, educate, learn, and entertain. Among the various kinds of multimedia services, video service is becoming an important component. Video service refers to the transmission of moving images together with sound [27]. Research on video transfers for multimedia services has been quite active in recent years, and video applications are expected to be the major source of traffic in future broad-band networks [32]. In this chapter, we treat the video traffic as a dynamic system, and apply a type-2 FLS to model it.

Dawood and Ghanbari [4] [5] used linguistic labels to model MPEG video traffic, and classified them into 9 classes based on texture and motion complexity. They used crisp values obtained from the mean values of training prototype video sequences to define low, medium, and high texture and motion. Chang and Hu [3] investigated the applications of pipelined recurrent neural networks to MPEG video traffic prediction and modeling. I/P/B pictures were characterized by a general nonlinear ARMA process. Pancha et al. [29] observed that a gamma distribution fits the statistical distribution of the packetized bits/frame of video traffic with low bit rates. Heyman et al. [10] showed that the number of bits/frame distribution of I-frames has a lognormal distribution and its autocorrelation follows a geometrical function, and they concluded that there is no specific distribution that can fit P and B frames. Krunz et al. [16], however, found that the lognormal distribution is the best match for all three types. All these methods belong to the statistical signal processing-based approaches, which match the mean and variance to a
known statistical distribution. Recently, Krunz and Makowski [17] observed that $M/G/\infty$ input models are good candidates for modeling many types of correlated traffic (such as video traffic) in computer networks.

As noted in [25], a shortcoming to model-based statistical signal processing is "...the assumed probability model, for which model-based statistical signal processing results will be good if the data agrees with the model, but may not be so good if the data does not." In real variable bit rate (VBR) video traffic, the traffic is highly bursty, and we believe that no statistical model can really demonstrate the uncertain nature of the I/P/B frames. Fuzzy logic systems (FLS) are model free. Their membership functions are not based on statistical distributions. In this chapter, we, therefore, apply fuzzy techniques to MPEG VBR video traffic modeling.

A survey of recent advances in fuzzy logic (FL) applied to telecommunications networks is discussed in [8]; it shows that FL is very promising for every aspect of communication networks. Recently, Tsang, Bensaou, and Lam [32] proposed a fuzzy-based real-time MPEG video rate control scheme to avoid a long delay or excessive loss at the user-network interface (UNI) in an ATM network. The success of fuzzy logic applied to communication networks motivates us to apply FL to video traffic modeling.

In Section 2, we briefly introduce MPEG video traffic. In Section 3, we introduce type-2 fuzzy sets. In Section 4, we model I/P/B frame sizes using supervised clustering. In Section 5, we present an interval type-2 TSK FLS where antecedents are type-2 and consequents are type-1. A design method for the type-2 TSK FLS is provided in Section 6. In Section 7, we apply the type-2 TSK FLS to MPEG video traffic modeling, and compare it against a type-1 TSK FLS. Conclusions are presented in Section 8.

In this chapter, $A$ denotes a type-1 fuzzy set; $\mu_A(x)$ denotes the membership grade of $x$ in the type-1 fuzzy set $A$; $\tilde{A}$ denotes a type-2 fuzzy set; $\mu_{\tilde{A}}(x)$ denotes the membership grade of $x$ in the type-2 fuzzy set $\tilde{A}$, i.e., $\mu_{\tilde{A}}(x) = \int_u f_x(u)/u, \ u \in J_x \subseteq [0, 1]$; $\triangledown$ denotes meet operation; and, $\sqcup$ denotes join operation. Meet and join are defined and explained in great detail in [12] [15].

2 Introduction to MPEG Video Traffic

MPEG (Moving Picture Expert Group) is an ISO/IEC standard for digital video compression coding, and has been extensively used to overcome the problem of storage of prerecorded video on digital storage media, because of the high compression ratios it achieves. MPEG video traffic is composed of a Group of Pictures (GoP) including some of the encoded frames: I (intra-coded), P (predicted) and B (bidirectional). I frames are coded with respect to the current frame using a two-dimensional discrete cosine transform, and they have a relatively low compression ratio; P frames are coded with reference to previous I or P frames using interframe coding, and they can achieve