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Emergence of region-based transmission when computation is unconstrained

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Abstract

Here, we study the emergence of a region-based approach when transmission costs, rather than computation constraints, limit the information upon which decisions are conditioned. We obtain that the average long-run loss of the transmission problem of size n is greater than that of the transmission problem of size Kn following a region-based approach, when computation is unconstrained. Hence a transmission problem of size Kn can achieve average costs lower than those of a transmission problem of size n by dividing the image into K quantizers of equal size n that imitate the prioritization protocol of an image of size n. In this case we have that additive and symmetric transmission costs, linearity and monotony of long-run loss, existence of cost-minimizing prioritization protocols, symmetric joint distribution of processes, not perfectly correlated processes, are among others some of the robust properties of constraints that drive the emergence of region-based transmission.

Keywords: Progressive transmission; Image size; Region-based approach; Prioritization protocol; Transmission costs; Long-run loss

1. Introduction

Our goal is to achieve continuously varying bit rates from a single compressed bitstream so that during the transmission of the coded data on the network, we can scale, or truncate, the bitstream at any place and send the most important bits of the bitstream. Such a scalable bitstream can provide numerous versions of the compressed image at various data rates and levels of quality. This feature is especially suited for image transmission over heterogeneous, multiuser, time-varying, and interactive networks.

García et al. [5] presented a first model that relates the facts of simplification of information, and planning time to the cost in bit-rate of the transmission, which can thus be optimized. Simplification of information to make decision-making feasible at low bit rates, and decision-making time to produce a new plan for transmission at each truncation time are both facts which reduce the efficiency of the decoded output. We assume that

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there is a ''natural language'' which is as rich as the number of details in the image, which concern the progressive transmission. The degree of lost in the decoded output which results from the transmission plan is related to the degree of simplification at each level of the hierarchy and to the richness of the language. The aim of the transmission system is to produce any output at minimum bit-rate cost. Once the optimum transmission system has been described, we can ask questions about the effect of an increase of complexity (in the details of the image) on the bit-rate cost of the transmission. In particular, García et al. [5] shows that under the presence of self-seeking coefficients which run counter the interest of the transmission system, we have that the result of an increase of complexity in the image details must be a higher likelihood of a region-based transmission system (i.e., it is very probable that the optimum transmission is a region-based system).

In order to distinguish between the effects of computation delay and transmission costs to the emergence of region-based transmission, we characterize in this paper the emergence of a region-based approach when transmission may be costly and there exists long-run loss (which aggregates time-by-time expected losses) but computation is unconstrained. In this context, ''emergence of the region-based approach'' means that the transmission problem of size Kn can achieve average costs lower than those of a transmission problem of size n by dividing the image into K quantizers of equal size n that imitate the prioritization protocol of an image of size n. The key difference between the two models, the one presented in García et al. [5] and that introduced in this paper, is that computation delay effects—because of the decision-making time to produce a new plan for transmission at each truncation time—are not present in the latter.

Rate distortion theory also calculates the optimum transmission system (with minimum transmission bit-rate) for a required picture quality. The main difference of our work with the optimization studied in the rate-distortion theory is the representation of constraints on the transmission problem. In this paper we represent them by axioms on an abstract set of transmission problems (Sections 2 through 4). This axiomatic approach has the advantage of highlighting the robust properties of the constraints (e.g., transmission costs, or expected loss) that drive the emergence of the region-based transmission.

2. Progressive transmission problems

We study a family of progressive transmission problems that are parametrized by the image size n. Our goal is to compare transmission problems of different sizes and to characterize the emergence of a region-based approach. To make clear the main difference between the present model and that introduced in García et al. [5], i.e., the computation delay effects are not present here, a first basic axiom is assumed:

Assumption 1. There are costs using any prioritization protocol but computation is unconstrained.

In our model, any image is associated with a set of discrete-time stochastic processes, indexed by $i \in \{1,\ldots,n\}$. Process i is denoted by $\{X_{i,t}\}_t$ where $X_{i,t}$ represents the actual demand in bits for transmission of coefficient c_i of the original image, at truncation time t.

The total demand in bits for transmission at t is given by:

$$X_t = \sum_{i=1}^{n} X_{i,t}.$$

The transmission problem, following any possible prioritization protocol π with transmission costs $C(\pi)$, controls the level of output at t centrally, noted as A_t, which is a random variable measurable with respect to the history

$$\{X_{1,t-d};\ldots;X_{n,t-d}\}_{d\geqslant 1}.$$

This problem is part of resource allocation problems—such as assigning output orders to n coefficients of the image transform—in which one of the steps is aggregating bit-rate costs in order to minimize the image distortion. The size of the transmission problem is n.

Since we assume the absence of a priori knowledge about regions of interest if, for quantizer formation, we partition a set of stochastic processes (each one corresponding to a coefficient of the image transform) into groups, their statistical properties should not depend on their identities. Hence, following Van Zandt and