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Effects of Finite-Precision Arithmetic in Enumerative Coding

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Abstract — The storage requirements of conventional enumerative schemes can be reduced by using floating point arithmetical operations instead of the conventional fixed point operations. The new enumeration scheme incurs a small coding loss. A simple relationship between storage requirements and coding loss is derived.

I. INTRODUCTION
Translation using enumeration has the virtue that the complexity (weight storage) grows polynomially with the code-word length contrasting the complexity of direct look-up which grows exponentially. Here we use a floating point instead of a fixed point representation of the weights. The floating-point notation is convenient for representing numbers that differ many orders of magnitude. In this notation, each weight is represented by s bits, and as a result, the hardware required for storage grows linearly with the codeword length n. The penalty attached to the finite-precision representation of the weights is that it will entail a (small) loss in code rate. A quantitative trade-off between the precision of the number representation and concomitant code redundancy will be detailed. We will apply the theory to the enumeration of (dklr) sequences.

II. ENUMERATION USING FLOATING-POINT ARITHMETIC
The hardware for implementing the enumeration algorithm comprises a (binary) adder, a subtracter, a comparator, and a look-up table of the pre-computed set of weights. The binary fixed-point representation of a single weight requires \( Rn \) bits per weight, where \( R, 0 < R < 1 \), is a constant. For the overall scheme, we need therefore storage proportional to \( Rn^2 \). We develop an enumeration method where the weights are specified in floating-point notation.

We employ a two-part radix-2 representation
\[
I = (m, e)
\]
to express the weight
\[
I = m \times 2^e,
\]
where \( I, m, \) and \( e \) are non-negative integers. The two components \( m \) and \( e \) are usually called mantissa and exponent of the integer \( I \), respectively. The translation of a weight into \((m, e)\) is easily accomplished. It is assumed that the exponent of each weight is represented by \( e_p \) bits.

Let \( I \) be the short-hand notation of one of the weights \( N^M(i) \). It is well known that the non-negative integer \( I, I < 2^n \), can be uniquely represented by a binary v-tuple \( \alpha = (x_{v-1}, \ldots, x_0) \), where
\[
I = \sum_{i=0}^{v-1} x_i 2^i.
\]