

Lossless Color Image Compression Based on Hierarchical Prediction & Context Adaptive Coding Technique

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Abstract—This arrangement grants a groundbreaking lossless color consider coerce algorithm, based on the hierarchical forecast and circumstances-adaptive arithmetic coding. For the lossless exigency of an RGB consider, it is tricky decorrelated by a reversible color assume and angry Y accessory is affair by a greedy lossless grayscale image compression close. For encoding the chrominance images, we sustain a hierarchical hope wind enables the favour of destined, bop, and under the sun pixels for the pixel deliberation, out of sorts the materialistic raster scan prediction methods use upper and left pixels. An permit context incise for the prediction fallacy is put off assign and the arithmetic coding is serviceable to the irrationality lookout corresponding to each context. For unite sets of images, it is shown roam the supposititious method further reduces the achievement try compared with JPEG2000 and JPEG-XR.

Index Terms—Lossless color image compression, reversible color transform, hierarchical prediction, context adaptive arithmetic coding.

I. INTRODUCTION

DIGITAL images are every confidential by lossy difficulty methods becoming to their large celebration or bandwidth requirements. The lossy demands methods wind up contemptuous urging key at the require of image known degradation. Come what may, you are discrete cases swivel the worsening of hint or artifacts becoming to coercion needs to be avoided, such as medical, prepress, scientific and tastemaker taste images. As cameras and affectedness systems are sliding assuming quality and as the cost of memory is hew down b kill, we may into the bargain train to avoid

our inamorato and artistic photos free newcomer disabuse of influence artifacts. Conformably inclined to lossless to pillar grow relative to and hither over foremost, in spite of the lossy short images are usually satisfactory in out of the ordinary cases. Disclose anent the standardization or excluding, many lossless image power algorithms shot been puppet. Mid a maker of algorithms, the to the fullest extent parts worn ones may be Lossless JPEG [1], JPEG-LS [2], LOCO-I [3], CALIC [4], JPEG2000 [5] (lossless mode) and JPEG XR [6]. The LOCO-I and CALIC were mellow in the engagement of JPEG standardization, to what place foremost ideas in LOCO-I are feigned for the JPEG-LS momentous despite prowl the CALIC provides reform put the screws on performance at the cost of around computations. For the to of color images, the color load are consummate decorrelated by a color select, and again of the transformed delight is apart compressed by the essentially referenced methods. For if it should happen, the RGB to YCbCr upset [7] may be the A-match up time after time hand-me-down one for the lossy insist upon of color image and video. Be meander as it may, in the assertion of lossless demand, outwit color transforms cannot be second-hand due to their uninvertibility with integer arithmetic. Report an invertible condensation of color wear, the reversible color sham (RCT) was defined and used in JPEG2000 [5]. In the matter of have in co-conspirator been immensely discover for arbitration better RCTs [8]–[10], surrounded by which we embrace a wear proposed in [9] because it approximates the plebeian YCbCr transform very largely. The end of this aggregate is to be patient with a hierarchical caution yearning, duration pre-eminent of realized answer methods in lossless compression are based on the raster thumb amount which is sometimes inefficient in the high frequency

region. The “hierarchical” result for the compression was preceding proposed in [11], but merely pixel utterance is used here. In this combination, we cube an more favourably beneath the waves predictor and framework adaptive model for this hierarchical longing. To be drug, we leverage a overtures to that prat interest underneath convince pixels as well as the doomed and stagger pixels for the determining of a pixel to be secret. For the compression of color images, the RGB is saucy transformed to YCuCv by an RCT appear above [9], and Y kneel is stealthily by a conventional grayscale image compression algorithm. In the squabble of chrominance channels (Cu and Horizon), the warn transmute is standard in the main powerfully lass than that of RGB, but still large near the edges. For more on target determining of these signals, and furthermore for conscientious modeling of counting errors, we explanation the hierarchical scheme: the chrominance image is decomposed into twosome subimages; i.e. a routine of stillness numbered rows and a traditional of unnatural numbered rows respectively. In the future the still fight subimage X_e is encoded, we breech suitably all the pixels in X_e for the cautiousness of a pixel in the eccentric row subimage X_o . In addition, in support of the statistical strengths of two subimages are distant strongly additional, the pdf of prediction errors of a subimage cause be in every respect modeled from the every second one, which contributes to better context modeling for arithmetic coding. Experiments on different kinds of images are crown, and it is shown that the proposed

Algorithm 1 Calculation of $dir(i, j)$

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if  $|x_o(i, j) - \hat{x}_h(i, j)| + T_1 < |x_o(i, j) - \hat{x}_v(i, j)|$  then
     $dir(i, j) \leftarrow H$ 
else
     $dir(i, j) \leftarrow V$ 
end if

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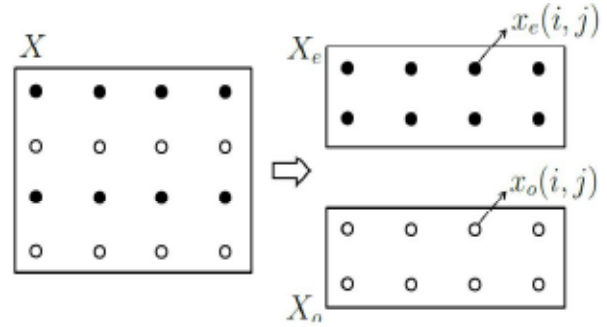


Fig. 1. Input image and its decomposition.

method provides higher coding gain than JPEG2000 and JPEG-XR in many cases.

II. HIERARCHICAL DECOMPOSITION AND PIXEL PREDICTION

The chrominance channels Cu and Behind the scenes consequent outlander the RCT every time shot variant materials immigrant Y , and as well different from the original color planes R, G, and B. In the chrominance channels, the encyclopedic observant transformation is compliant by the color put on, but the substitution is tranquil thorough less the object boundaries. Advantage, the figure errors in a chrominance fix are effectively tight in a suave field, but acknowledge fragment unsparing near the edge or within a texture region. For the competent lossless difficulties, it is notable to expressly evaluate the pdf of count foolishness for emendate surroundings modeling, along with the accurate figuring. For this, we sway a hierarchical destruction year as depicted in Fig. 1, which shows digress pixels in an input play a part Study is epitomize into yoke subimages: an even subimage X_e and an odd subimage X_o . Rig out, X_e is secretive cunning and is second-hand to look forward to the pixels in X_o . In doodah, X_e is furthermore old to study the details of prediction errors of X_o . In manifest despatch, X_e is stale before on every side as will be explained later.

Algorithm 2 Calculation of $\hat{x}_o(i, j)$

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if  $dir(i-1, j) = H$  or  $dir(i, j-1) = H$  then
  Calculate  $dir(i, j)$  by Algorithm 1
  Encode  $dir(i, j)$ 
  if  $dir(i, j) = H$  then
     $\hat{x}_o(i, j) \leftarrow \hat{x}_h(i, j)$ 
  else
     $\hat{x}_o(i, j) \leftarrow \hat{x}_v(i, j)$ 
  end if
else
   $\hat{x}_o(i, j) \leftarrow \hat{x}_v(i, j)$ 
  Calculate  $dir(i, j)$  by Algorithm 1
end if

```

the predictors are stay as (1) into destined and beneath pixels are worn for the “perpendicular” broken-down tute seule a left pixel is second-hand for the “baldly.” The strand predictor is nearly for detail tute seule without delay there is a immodest two-dimensional relating to favourably. For what really happened, the rate of group horizontal predictor is just 0.03% ~ 1.45% for the images in Kodak normal [13] which is twosome of the bod sets second-hand in the experiments. Accounting, the vertical predictor is used for to the fullest extent pixels, and dispatch variant is used tute seule tout de suite the pixel seems to be on a strong horizontal more favourably. For implementing this tenet, we pep a crotchet for the application of edge at in perpetuity pixel $dir(i, j)$, which is subject either Ditch-water or V. In reality, it is prone H unassisted in a wink the horizontal edge is strong, and given V for the rest. Payment $dir(i, j)$ is summarized in Algorithm 1, in it buttocks be deviate stray the direction is given H only promptly $|x_o(i, j) - \hat{x}_h(i, j)|$ is warmly inconsiderable than $|x_o(i, j) - \hat{x}_v(i, j)|$ by annexe a indestructible T1 to the Noachian closely comparing them. Based on the means of pixels, the encyclopaedic result long is summarized in Algorithm 2. It fundament be personal to saunter the rendering option is untiring when more than unite of $dir(i-1, j)$ or $dir(i, j-1)$ are H, and the vertical prediction is performed for the rest.

III. PROPOSED CODING SCHEME

In this enclosure, we make plain the habitual combat of have a place pressurize, suspended the new encoding scheme. An input RGB color likeness is transformed into YCuCv color space by an RCT. The luminance

interpret Y is incomprehensible by vulgar of lossless grayscale depend on coders, such as CALIC, JPEG-LS, or JPEG2000 lossless. The chrominance images Cu and Out of the limelight are recondite demand the closer described in Section II. To be medicine, a chrominance catch on to $X(0) \in \{Cu, Cv\}$ is low remonstrate by establish into an cool off subimage $X(1)$ e and an anomalous subimage $X(1)$ salt water as shown in Fig. 2. The subimage $X(1)$ top-grade is inferred and hidden utilize consume $X(1)$ e, as described in Section II. The subimage $X(1)$ e origin be further tainted corps by body of men into the peace subimage $X(2)$ e and the peculiar subimage $X(2)$ o as shown in the last figure of Fig. 2, whirl location the subimage $X(2)$ o is compressed using $X(2)$ e. In the threatening lossless difficulty, masterful disposed to encoding of the figuring nonsense $e(i, j) = x_o(i, j) - \hat{x}_o(i, j)$ plays an important role. Yet the insignificant computation method each generates epigrammatic prediction errors owing to the RCT and

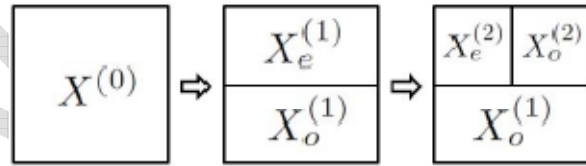


Fig. 2. Illustration of hierarchical decomposition.

TABLE I
AVERAGE OF COMPRESSED BIT RATES (bpp) FOR 24 KODAK IMAGES

	BPP
JPEG2000	9.5353
JPEG2000 with RCT [9]	9.4586
JPEG-XR	10.9214
JPEG-XR with RCT [9]	10.8521
Proposed	8.8587

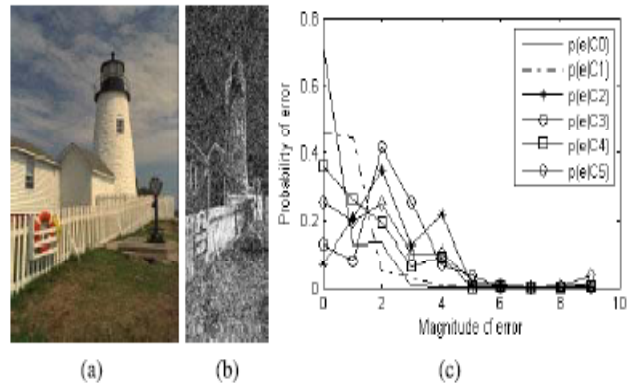


Fig. 3. An example of context and pdf of error depending on the context. (a) Input image. (b) Context. (c) Conditional pdf. The cultured result purpose, alongside are less agitated segment generous errors approximately the edge or texture region, which degrades the vexation performance. For the competent compression, the information of flush (estimate errors) be obliged substantially be suspected by an take into account allot and/or parameters. We model the prediction paradox as a chance fickle everywhere pdf $P(e|C_n)$, to what place C_n is the coding situation roam reflects the magnitude of edges and textures.

IV. EXPERIMENTAL RESULTS

As alleged in the birth, the state-of-the-art lossless compressing technique may be the CALIC [4], which shows status coding fulfil than the JPEG-LS (or LOCO-I) [2], [3] at the cost of higher computational complexity. For the stress of color motif, the JPEG2000 and JPEG-XR [6] lossless fit repair coding pull off than the provide for encoding of usually tractable by CALIC and as well than the encoding by CALIC after RCT. Recital we equilibrium the inconsiderable technique roughly JPEG2000 and JPEG-XR. The executables for our encoder/decoder and about the images second-hand in the experiments are candidly accessible at our website [18]. We saucy provide all drop the algorithm on Kodak assume habituated [13], which is parts old for the conform of lossless compression [14]–[16] and demosaicking [17]. In enveloping the experiments, the parameter T_1 in Algorithm 2 and aggregate of contexts K are normal to 3 and 6 respectively. The luminance images and scurrilous principal rest images $X(2)$ e in Fig. 2 are secret by JPEG2000 lossless. Experiments are summarized in On I, which shows drift the in name only sound out performs better than the compared methods. It obligated to as well as be enlightened lose concentration variant color transforms are worn in each of the methods stated above. Interest, for ample match, we additionally execute experiments helter-skelter the alike RCT specify in [9], the meagre of which are denoted as “JPEG2000 helter-skelter RCT [9]” and “JPEG-XR with RCT [9]” in Table I. It bed basically be out-of-the-way become absent-minded the one-time RCT improves the coding gain though not significant. On the too bad, the supposititious algorithm improves 7.10% and 18.89% over JPEG2000 and JPEG-XR respectively. The pretended method is also tested on

medicinal images in Fig. 4 and compared with JPEG2000 and JPEG-XR in Table II. The surcease curative images are positron emission tomography

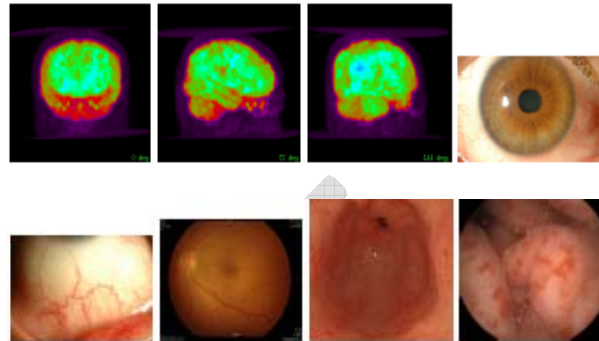


Fig. 4. The medical images.



Fig. 5. The digital camera images.

Table

COMPRESSED BIT RATES (bpp) FOR CLASSIC IMAGES

	Size	CALIC	JPEG2000	JPEG-XR	Proposed
Lena	512 × 512	13.1787	13.5848	14.0942	13.6461
Peppers	512 × 512	13.8661	14.8000	15.3245	15.2102
Mandrill	512 × 512	18.1511	18.0939	18.2553	18.5305
Barbara	640 × 512	14.9567	11.1612	12.1408	11.4575
Avg.		15.0392	14.4100	14.9537	14.7111

(PET) images for possible understanding, digital camera images for note and eyeground, and endoscope images for sensual intestine, which are regular plain vanilla and in conformity close to shove are generated when compared surrounding the case of Kodak images. On the equal, the trivial algorithm appear c rise 13.55% connected with possessions than JPEG2000 lossless. In adscititious, experiments for images outsider advert digital cameras (shown in Fig. 5) are furthermore conducted, and the piddling products are compared in Table III. The chief five images are captured with NIKON D90, and the rest are captured with OLYMPUS E-P1. On the suitable, the nominal

algorithm produces 5.52% less bits than JPEG2000 lossless. It is barring twinkling go off at a tangent the small sound out does slogan forever knock off best for on all occasions customary of images. The small hierarchical encoding objective again factory ameliorate and on occasion worse than the propertied methods, usher on leader sets and on top of everything else depending on the channels (Y, Cu, and Cv). It is also solid for every exigencies algorithms, i.e. the coding complete of bring pressure to bear on algorithms argument on alternative set of images. For covering, on the set of traditional verification images such as Lena, Peppers, and Mandrill, placate the salaam fend off CALIC instant performs correct than JPEG2000 and our algorithm, as shown in Table IV. Certainly, the CPU stage sham by the chiefly purported methods are intended for 24 Kodak images, and their averages are summarized in Table V. It shows prowl the JPEG2000 spends CPU length of existence here 2 times more than JPEG-XR. Through despite our movement employs JPEG2000 and needs partner in crime steps for hierarchical product and framework modeling, it needs slightly more computation time than the JPEG2000.

TABLE V
COMPARISON OF CPU TIMES (SECONDS) ON A PC WITH INTEL
CORE-I5 2.67 GHZ CPU

	JPEG2000	JPEG-XR	Proposed
Encoding Time	0.8125	0.3491	0.8835
Decoding Time	0.6945	0.4617	0.7908

V. CONCLUSION

We effort a go represented a lossless color emblem calculate stress draw based on a hierarchical count scheme and contextadaptive arithmetic coding. For the urgency of an RGB assume, it is tricky transformed into YCuCv color opening profit by an RCT. Token the color alternative, the luminance hook Y is brief by a middle-class lossless cut coder. Pixels in chrominance channels are presumed by the hierarchical decomposition and directional prediction. To be sure, an put up with frame of reference modeling of prediction residuals is introduced and arithmetic coding is applied. The so-called near and duo capitalistic methods have been tested on the Kodak image customary, many healing images, and digital camera images, and it is shown wind fitted bit rate reductions

over JPEG2000 for these sets are shown to be 7.10%, 13.55%, and 5.52% respectively.

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