Multimedia Information Compression and Error Correction Techniques for Satellite Communications

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Abstract

In this paper, compression and error correction techniques that were developed in conjunction with the COMETS satellite project are described. The results of experiments using the satellite are also reported.

I. Introduction

In our work for the COMETS project, we have been studying compression and error correction techniques for multimedia information sources [1] [2]. In particular, we are interested in "human communication", i.e., communication between humans. This involves information such as natural language text and facial images. When information sources are restricted to these types of "human" sources, different approaches to compression and error correction may be utilized. In our research, we propose an "intelligent" approach, which is outlined in Fig. 1.

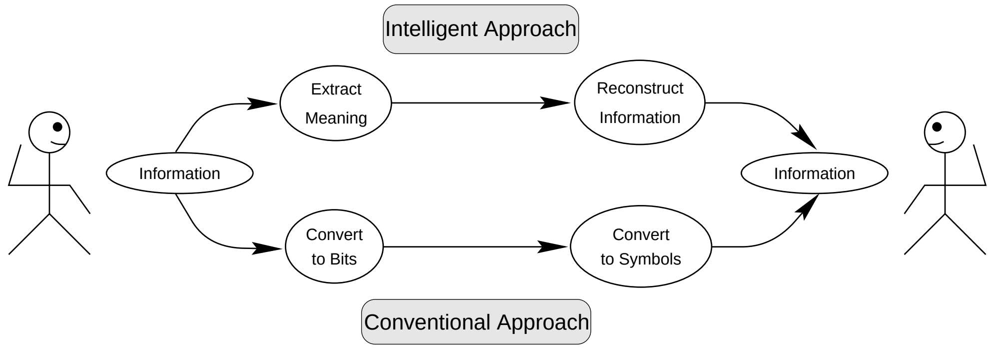

Fig. 1. Conventional vs. intelligent communication

In conventional approaches, the statistics of the information are used to compress or correct errors. This approach works well for many kinds of data, such as images and text. However, the amount of compression that can be obtained is limited by the entropy of the data. In order to improve the compression or error correction efficiency, information other than just the statistical properties of the data must be used.

In our "intelligent" approach, the meaning of the information is taken into account when compression or error correction is performed. In this paper, we show that more efficient compression and error correction can be achieved this way.

II. Information Compression

A. English Text

The communication system that is considered in this paper is shown in Fig. 2 [3]. We assume that two English speaking people are communicating over a noise–less communication channel

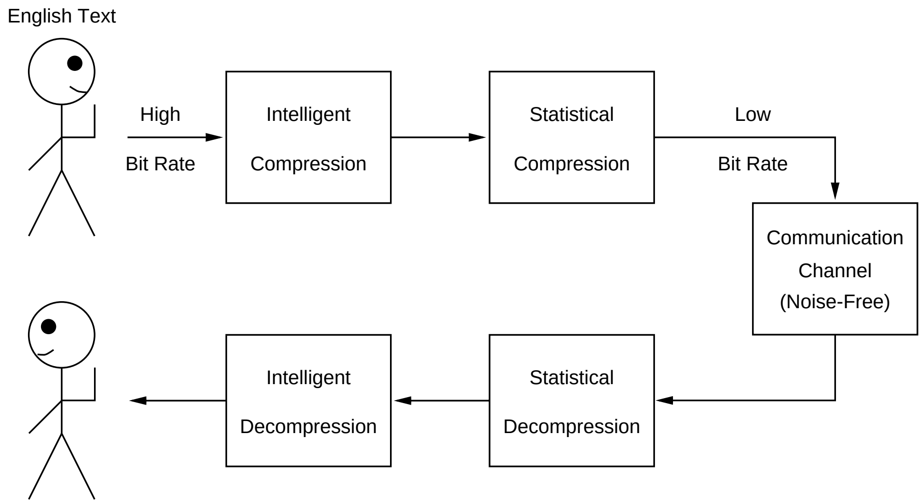

Fig. 2. Communication system model for intelligent English text transmission

using written text. This situation can arise, for example, when two people are communicating through a computer network by typing at a computer terminal.

The compression part of the system is divided into "intelligent" compression and "statistical" compression. The intelligent compression part of the system removes characters from the text until no more characters can be removed without changing the meaning of the text. In this type of system, the intelligent compression part is lossless in the sense that the meaning of the text remains the same, but is lossy in the sense that the original text may not be exactly reconstructed by the decompression algorithm. The statistical compression part of the system is a lossless, one–pass universal compression scheme. In this paper, we use the Lempel–Ziv (LZ) algorithm.

To estimate the compression improvement obtained by the intelligent compression (IC) algorithm, we compared the size of several English text files to the size of the files after intelligent and statistical compression and to the size of the file when only statistical compression (SC) was done. The results are shown in Table I.

TABLE I
COMPRESSION COMPARISONS

Size	File 1	File 2	File 3	File 4
Original	53533	40730	65746	47022
After IC Only	40730	30823	47022	33621
After SC Only	17395	13396	26685	19693
After IC & SC	14496	11131	21327	15648
Improvement	5.4%	5.6%	8.1%	8.6%

IC: Intelligent Compression
SC: Statistical Compression (LZ)

The improvement shown in the table is the difference in compression ratios between combined IC & SC and SC only. Here, we define the compression ratio as the size of the compressed file expressed as a percentage of the original file size, i.e.,

$$\text{Compression Ratio} = \frac{\text{compressed file size}}{original\ file\ size} \times 100\%. \tag{1}$$

From the table, we can see that the combined intelligent and statistical compression system improves the compression ratio by an average of roughly 7.0%.

B. Facial Images

The image transmission system considered in this paper is shown in figure 3. A CCD camera connected to a workstation is used to load the image. The workstation then processes the image and converts it to a series of low rate commands that describe the movement of the image. This information is transmitted over a low rate channel and then the original image is reconstructed using a workstation at the receiver.

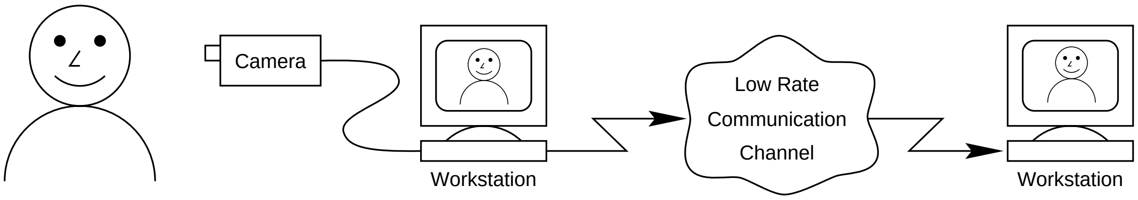

Fig. 3. Intelligent image transmission system.

A block diagram of the compression method is shown in figure 4. First, a reference image is transmitted. This provides the receiver with an image which can be used to reconstruct the subsequent images. Next, image frames are scanned by the camera and compared to the previous image. The workstation extracts movement information such as “head tilted sideways” and “eye closed”. This information is converted into a set of commands and transmitted.

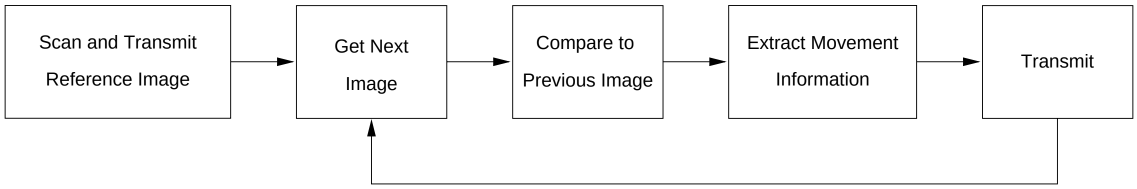

Fig. 4. Intelligent image compression algorithm.

An 8–bit colour image of 200 by 200 pixels transmitted at 30 frames per second requires a data rate of about 80 megabits per second. Even with some standard compression algorithms such as JPEG, the data rate is still about 8 megabits per second. Using the proposed method, the images can be sent at a rate of less than 1000 bits per second.

As an example of our intelligent image compression algorithm consider the image sequence shown in Fig. 5 [4]. As a first step to aid in the extraction of facial image changes, colour markers were used. There are six markers located: above each eye, below each eye, above the mouth and below the mouth. Our algorithm locates these markers and calculates their relative positions between frames. The position changes, along with the first image, can be used to reconstruct the image sequence at the receiver.

The position changes that result from the above image sequence is show in Table II. The parameters shown in this table, along with the reference image, are all that are needed to transmit the facial image.

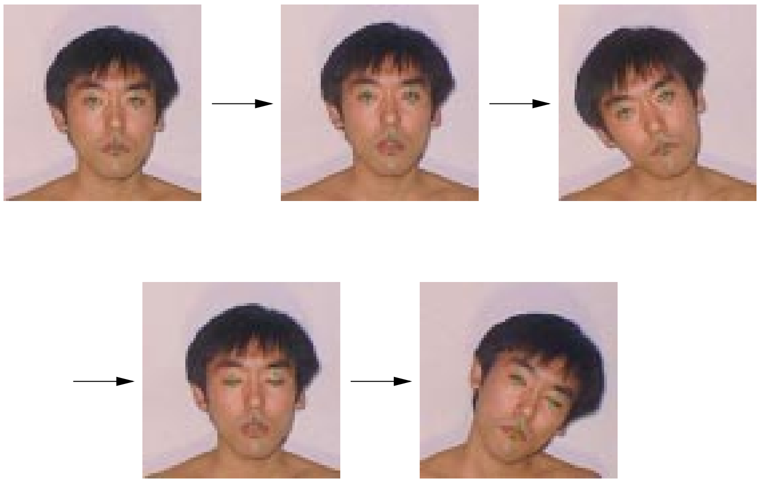

Fig. 5. Intelligent image compression: example image sequence

TABLE II
EXTRACTED PARAMETERS FROM THE IMAGE SEQUENCE IN FIG. 5

Frame #	Change in Head Tilt	Change in Lateral (x, y) Position
1 (Ref.)	0	0
2	-0.022	$(-2.0, -5.0)$
3	-0.547	$(-20.3, 11.3)$
4	0.524	$(23.3, -4.3)$
5	-0.632	$(4.3, 10.0)$

A block diagram of the decompression technique is shown in Fig. 6. The reference image is first received and stored. Next, the movement information for each frame is received. The receiver uses the movement information and the previous image to reconstruct the current frame from the reference image.

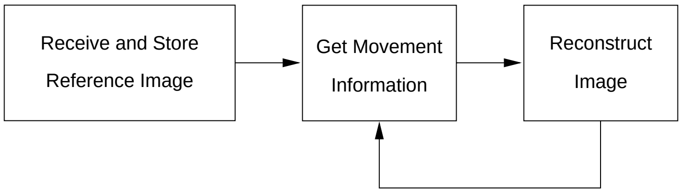

Fig. 6. Intelligent image decompression algorithm

A simple reconstruction example is shown in Fig. 7 [5]. In this figure, the original facial image (Fig. 5 is not recreated, but the movement is the same as the original image. Further work on reconstruction of the original facial image is necessary, but we have shown that the basic idea is valid.

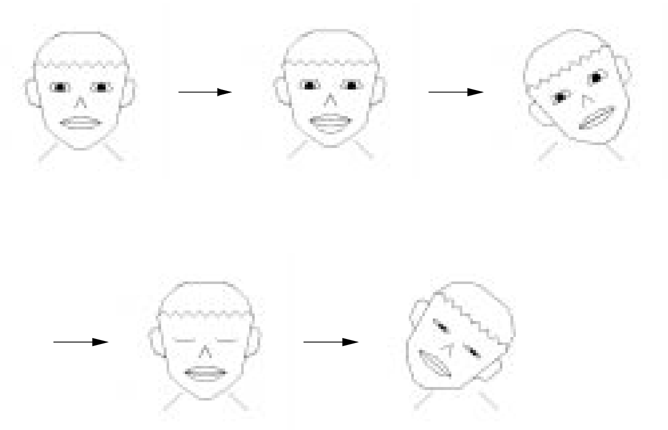

Fig. 7. Intelligent image decompression: reconstruction example

III. Error Correction

In intelligent communication systems, not all the information is necessary to understand the message. On a character level, if some of the letters are missing or incorrect, the word can still be recognized by a human receiver. On a word level, not all the words are necessary to understand the sentence.

We have proposed several error correction schemes that take into account the properties of the information source [6] - [14]. For two importance levels, the system model is shown in Fig. 8.

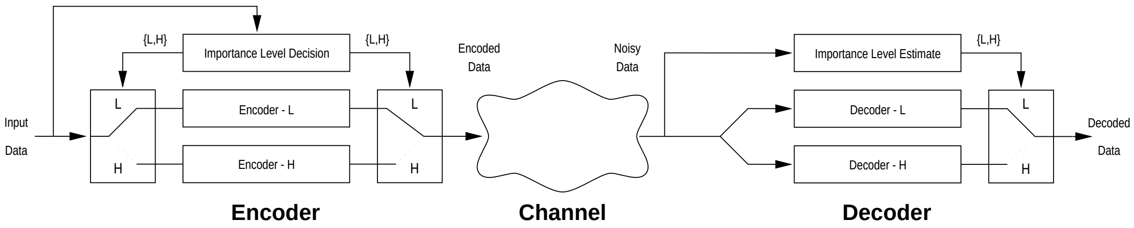

Fig. 8. Intelligent error correction system model

In these UEP codes, the error protection capability of the code is changed depending on the importance of the information. This is done by using a different code for each level of importance. Since we use convolutional codes in this work, the bits are divided into frames. The importance level is the same for all bits in a frame.

To decode the data, the received bits are decoded with all decoders in parallel. The bits from the decoder that results in the smallest metric are chosen as the estimates of the original information. Since we do not add extra information as to which encoder was used to encode the data, it is necessary to somehow distinguish between coded bits from each encoder.

Using just convolutional codes, it is difficult to distinguish between bits from each encoder, because the transmitted bits are either "0" or "1" irrespective of the encoder. To create differences among the outputs of each encoder, Trellis Coded Modulation (TCM) is used. Each encoder uses a different signal constellation, so that the receiver can distinguish between bits from each encoder.

The performance of this system is shown in figure 9 for two signal constellation types. From this figure, we can see that the important bits (marked with an 'H') are protected more than the less important bits (marked with an 'L'). For comparison, an uncoded system and an equal error protection system (Coded QPSK) are shown. The error rate of the important bits in the unequal error protection scheme is better than that of the equal error protection scheme.

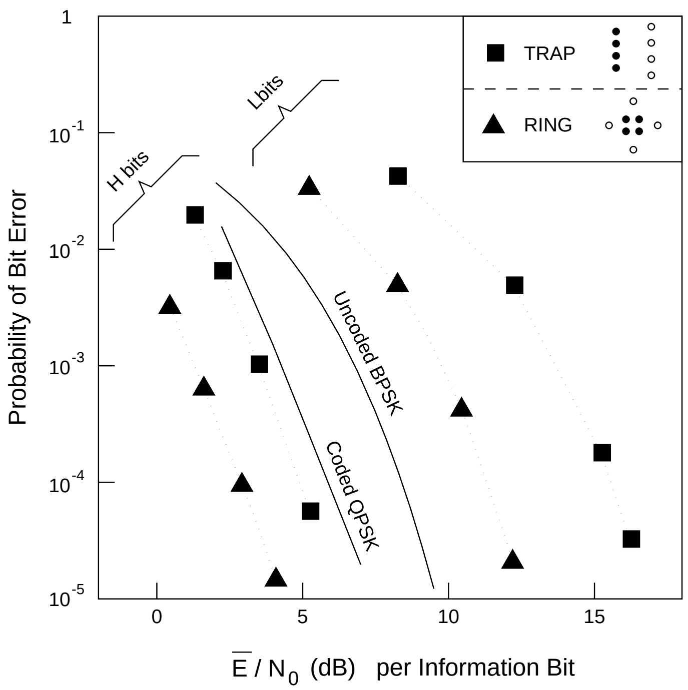

Fig. 9. Performance of the intelligent error correction system

IV. Satellite Experiments

We proposed using the COMETS satellite to test both the image transmission and error correction algorithms that we introduced in the previous sections. Unfortunately, due to the limited experimental time available, we were only able to partially test our error correction algorithms [15].

The experimental setup used to test our algorithm is shown in Fig. 10. The data is encoded using a workstation (W.S.1) and then transmitted using the TCP/IP protocol to an ATM switch (ATM SW). The ATM switch transmits the data to a modem, which in turn sends the data to the COMETS satellite via the ground station (ES). On the reverse link, the data is sent to the receiving workstation (W.S.2) and decoded.

Using the experimental system described above, binary data was encoded and transmitted via the COMETS satellite. In all, 14 different sets of data were transmitted 10 times each for a total of 2.54×10^8 transmitted bits. The received data was compared with the transmitted data and it was found that even without encoding the data, no errors occurred. This indicates with high confidence that the probability of a bit error through this channel is less than 10^{-6}.

The reason for such a low error probability is due to the fact that there is additional error control coding that is added by the TCP/IP and ATM protocols and the modem. Therefore, in order to evaluate channel coding techniques, a transmission system that does not include extra error control coding is necessary.

V. Conclusions

In this paper, our contributions to the COMETS project have been summarized. We have proposed text and image compression algorithms that work for natural information sources such as natural language text and facial images. We have also proposed error correction algorithms for information sources which produce messages that have different importance levels. Finally, some experimental results obtained using the COMETS satellite were shown.

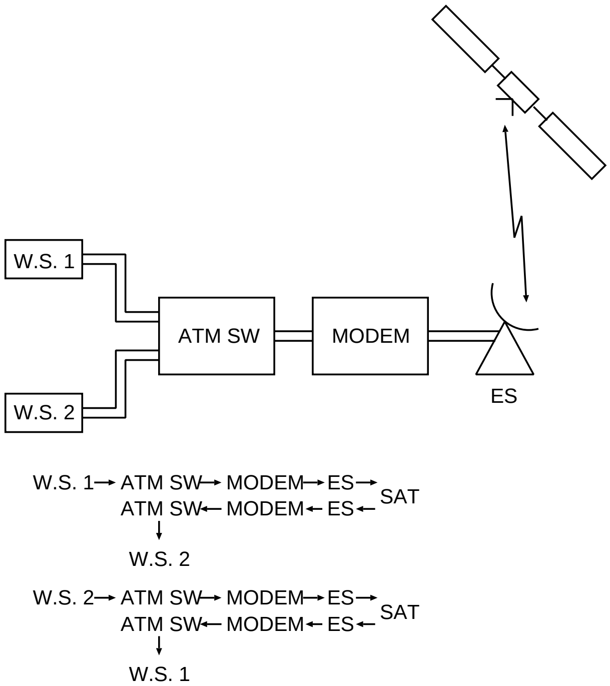

Fig. 10. Intelligent error correction experimental system

The results of our research are not limited in applicability to the COMETS project, but are important contributions to various other research fields such as information theory. Also, even though only limited experiments could be done, our ideas are valuable to such projects as the Ka-band ground-satellite communication system project that will start this year.

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