INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

T.80

(09/92)

TERMINAL EQUIPMENT AND PROTOCOLS FOR TELEMATIC SERVICES

COMMON COMPONENTS FOR IMAGE COMPRESSION AND COMMUNICATION – BASIC PRINCIPLES

Recommendation T.80

FOREWORD

The CCITT (the International Telegraph and Telephone Consultative Committee) is a permanent organ of the International Telecommunication Union (ITU). CCITT is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The Plenary Assembly of CCITT which meets every four years, establishes the topics for study and approves Recommendations prepared by its Study Groups. The approval of Recommendations by the members of CCITT between Plenary Assemblies is covered by the procedure laid down in CCITT Resolution No. 2 (Melbourne, 1988).

Recommendation T.80 was prepared by Study Group VIII and was approved under the Resolution No. 2 procedure on the 18th of September 1992.

CCITT NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized private operating agency.

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INTRODUCTION

This Recommendation was prepared by CCITT SG VIII. The requirements, contained in clause 5, however, were forwarded to an informal CCITT-ISO/IEC "Joint Photographic Experts Group" (JPEG). The task of this Group was to develop a universal progressive/sequential compression algorithm for any type of colour model.

During the development phase extensive testing and comparison of various techniques showed, that although the original goal was technically feasible, the initial solution did not produce the best compression and image-quality results for alll the image types addressed. Therefore it was decided that JPEG should develop a progressive/sequential continuous-tone color and gray scale image compression technique (described in Recommendation T.81), while a newly formed separate group, CCITT-ISO/IEC "Joint Bi-level Image Group" (JBIG) should develop a separate (but from a functionality point of view similar) progressive/sequential bi-level (limited multi-level) image-compression technique (described in Recommendation T.82). Thus, there are many commonalities between the two techniques (such as their functionality, the use of a joint entropy coder, etc.), but the two techniques are different from an algorithm point of view. Reference to the JPEG and JBIG developed algorithm are provided in clause 2, Normative references. Both techniques were jointly standardized by CCITT and ISO/IEC.

Recommendation T.80

COMMON COMPONENTS FOR IMAGE COMPRESSION AND COMMUNICATION – BASIC PRINCIPLES

(1992)

The CCITT,

considering

(a) that the CCITT seeks the most efficient methods of coding, communication and storage of images;

(b) that there is a growing interest in telematic services (such as facsimile, videotex, teleconferencing) and other CCITT applications to transmit images on telecommunication networks with varying speeds;

(c) that there is a growing demand for multilevel (including gray-scale and continuous tone color) imagery;

(d) that there is a trend to multifunctional terminals participating in more than one telematic services and/or other CCITT and/or data-processing applications;

(e) that with the introduction of new telecommunication network technologies, such as ISDN, there is a growing tendency to provide multiple CCITT services and/or other applications on the same telecommunication network;

(f) that there is an urgent demand for interworking among telematic services (and other CCITT applications) used for image-communication and/or image-storage;

(g) that there is a strong convergence of image-processing, image-storage and image-communication techniques;

(h) that there is strong tendency toward introducing "soft-copy" (i.e. screen oriented) image-communication services/applications;

(i) that there is a need for harmonization of "soft-copy" (i.e. screen oriented) and "hard-copy" (i.e. print-oriented) image presentation modes, within the same, or among several CCITT services/applications,

recognizing

(j) that while several established techniques (see Recommendations T.4 and T.6) for efficient coding of images containing black and white text and line-drawings exist in CCITT without using new image-compression techniques, the needs expressed above can only partially be satisfied, unless new image-compression techniques are provided,

unanimously recommends

that in addition to image-compression techniques defined in Recommendations T.4 and T.6 a new generation of image-compression techniques containing new or improved properties (including, but not limited to: gray-scale/colour, progressive/sequential image build-up, lossy/lossless compression, be defined according to the T.80-Series Recommendations.

1 Scope

The T.80-Series Recommendations are applicable to a wide range of CCITT applications which require use of compressed still images. Such images can range from bi-level to continuous-tone single-color and multi-color still digital image. It is applicable to a wide range of CCITT applications which require use of compressed images.

This Recommendation is the introduction to the T.80-Series Recommendations. Recommendations T.81 and T.82 describe the individual image compression techniques.

This Recommendation describes the basic principles of the requirements to be satisfied by the new compression techniques, the relation of those compression techniques to the individual CCITT applications and services.

This Recommendation does not specify the individual compression techniques to be used. Neither does it specify, for a given application, a complete representation of coded image data, nor specify an application that is using any of the new compression techniques.

2 Normative references

The following CCITT Recommendations and ISO/IEC International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and International Standards are subject to revision.

[1] CCITT Recommendation T.81 (1992) | ISO/IEC 10918-1:1992, *Information technology – Digital compression and coding of continuous-tone still images - Part I: Requirements and guidelines*.

[2] CCITT Recommendation T.82 (1992) | ISO/IEC 11544:1992, *Information technology – Coded Representation of Picture and Audio Information – Progressive Bi-level Image Compression*.

Informative references to other related CCITT Recommendations, ISO/IEC Standards and application oriented CCITT Recommendations are provided in the References clause.

3 Definitions

For the purposes of this Recommendation, the following definitions apply.

3.1 **bi-level image**

An image with two distinct levels of predefined colors (e.g. a typical facsimile image is a bi-level black-and-white image).

3.2 **bit-plane**

An array (or “plane”) of bi-level symbols constructed from an image by choosing a particular bit from each pixel.

3.3 **byte**

Eight bits of data.

3.4 **coding process**

A general term referring to an encoding process, a decoding process, or both.

3.5 **color image**

A bi-level or multi-level image containing more than one color component, defining the full color specification of that image.

3.6 **color component**

One of the two-dimensional arrays which comprise a color image. The meaning of the color component is defined by the respective color model used.

3.7 **color model**

A defined way of describing colors. The color models selects the appropriate color components that are used to describe a specific color of an image sample.

3.8 **complete representation of a coded image**

A T.81 or T.82 data-stream embedded in the application (data) environment of a given CCITT application or service (e.g. in Photographic Data Syntax of Videotex).

3.9 **compression**

Reduction in the number of bits used to represent source image data.

3.10 **continuous-tone image**

An image whose color components contain a sufficient number of bits (color steps) per pixel, that the subjective appearance of the image appears continuous (e.g. 256 levels of gray provide the subjective impression of a true gray-scale image).

3.11 **decoder**

An embodiment of a decoding process.

3.12 **decoding process**

A process which takes as its input compressed image data and outputs either an equal to or similar to the original uncompressed image.

3.13 **(digital) (still) image**

A two-dimensional spatial array of image component data without time dimension, or a set of such arrays.

3.14 **dithering**

A technique applied to single bit-plane images, which makes the single bit-plane image appear subjectively as a continuous-tone image. When dithering is used in conjunction with a fixed image resolution, the result is a perceived "increase" in gray-levels. At the same time, however, the perceived image resolution decreases.

3.15 **encoder**

An embodiment of an encoding process.

3.16 **encoding process**

A process which takes as its input an original image as its input and outputs compressed image data.

3.17 **entropy coder**

Any lossless method for compressing data.

3.18 **fixed-resolution progressive mode**

A progressive image encoding/decoding process, whereby the quality of the image is improved by each successive step, while the original resolution of the image remains unchanged.

3.19 **gray-scale image**

A continuous-tone image with one color component only.

3.20 **half-toning**

An artificial coloring process (similar to dithering) used in printing that is applied to the bit-planes of the primary printing color components, and which results in a printout that subjectively appears to have continuous-tone color characteristics.

3.21 **"hard-copy" image**

An image which has been printed on an output device (a fixed, higher resolution image is usually expected).

3.22 **hierarchical progressive mode**

A progressive encoding/decoding process, such that, when decoding, a lower resolution image is decoded first, then by successive decoding steps, the resolution of the image is increased horizontally and vertically by predefined factors (usually by 2). In Recommendation T.82 this is the only type of "progressive" mode defined.

3.23 **image data**

Either source image data or reconstructed image data.

3.24 **interleave**

A sampling of different color components with different sampling frequencies. It results in different size of image resolutions for different color components. If correctly applied, remarkable compression gain can be achieved.

3.25 **limited multi-level image**

A term denoting that the precision with which each color component of a color image, or the single component a gray-scale image is specified, is limited to about two to seven bits.

3.26 **lossless**

A descriptive term for encoding and decoding processes in which the output of the decoding procedure is (data) identical to the input data to the encoding process.

3.27 **lossy**

A descriptive term for encoding and decoding processes which are not lossless, i.e. the decoding process output (data) is not identical with to the encoding process input (data). However, a lossy encoding and decoding process may produce an image with subjectively excellent image quality. Lossy coding compression is often applied in order to gain additional image compression.

3.28 **multi-level image**

A term for describing the precision-range of color components of a gray-scale or color image. Multi-level includes precision starting from about three levels (bits) to usually eight levels, but for some special applications 12, 16 or even higher.

3.29 **picture**

A bounded representation of visual information.

3.30 **picture coding**

The presentation in digital form of a picture, particularly for storage, interchange or processing.

3.31 **pixel**

One picture element of an image which is described by a rectangular array of such elements.

3.32 **pixel aspect ratio**

Definition of the actual shape of a single pixel, as defined by an application using the T.80-Series Recommendations.

3.33 **photographic coding**

A technique for representing pictures by means of pixels, using high resolution and a wide range of grey levels and/or colors giving a natural appearance.

3.34 **progressive behaviour**

A coding technique shows progressive behaviour if an image is first coded as a lowest resolution layer image and then is successively increased in resolution by means of differential layer images.

3.35 **progressive coding**

A method of describing the entire image is first described at a lower image quality (i.e. lower resolution image or an image without details) and then step-by-step successively build up and improve to the desired final image quality (i.e. final image resolution or image with many details).

3.36 **progressive-compatible sequential coding**

In Recommendation T.82, a method of coding an image, in which the image may be segmented into stripes, the image stripes are coded in sequence, and within each sequence, and within each stripe the image is coded to full resolution progressively. This is compatible by stripe/layer data reordering with progressive coding.

3.37 **quantization**

A process to represent an analogue signal source by an appropriate digital value.

3.38 **sample**

A sample represents one element in the two-dimensional array which comprises a component. In the image conversion process of the analogue source image into a digital image, “samples” are taken, line by line, in regular intervals. Depending on the application-dependent sampling process, the relation of samples to pixels is determined by factors, such as color model, interleave, sampling geometry, etc.

3.39 **sequence behaviour**

A coding technique shows sequential behaviour if portions of the image near the top are completely described before portions below have been described at all.

3.40 **sequential coding**

A method of describing an image in which portions of the image near to the top are completely described before portions below have been described at all.

3.41 **single-progression sequential coding**

In T.82, a method of coding an image, such that the image is fully coded in a single resolution layer, line by line, from left to right and top to bottom, without reference to any lower resolution images. This is compatible with progressive coding and progressive-compatible sequential coding, if the number of differential layers is zero.

3.42 **“soft-copy” image**

An image which is intended for a visual display unit as output device (thus usually variable lower resolutions are expected).

3.43 **spatial resolution**

The number of pixels used to describe a region of an image of fixed spatial size.

3.44 **subsampling**

A sampling technique whereby the sampling frequency of one color component is half, third, quarter, etc. of the sampling frequency of another color component. E.g. in CCIR 601 the sampling frequency of the chrominance component is half of the luminance component. Thus the chrominance component is subsampled.

3.45 **“tool-kit”**

A concept of providing a full set of common functional componentents (e.g. progressive build-up mode, lossy compression etc.) for image compression to be used by various image coommunication applications. Usually a given application uses only a logical subset of the entire “tool-kit”.

4 Abbreviations

CPU	Central Processing Unit
DPCM	Differential Pulse Code Modulation
DCT	Discrete Cosine Transform
JBIG	Joint Bi-level Image Group of CCITT-ISO/IEC
JPEG	Joint Photographic Experts Group of CCITT-ISO/IEC
MMR	Modified Modified READ Code (Algorithm used in Recommendation T.6)
TP	Typical Prediction (part of Recommendation T.82)
VLSI	Very Large Scale Integration

5 Requirements

5.1 *Data quantization, sample precision*

An overview of various type of picture data, presentation forms, and introduction to the basic concepts picture data is provided in Annexes A and B of ISO/IEC 9281-1.

This Recommendation deals with still images made up of two-dimensional pixel arrays. Motion images – containing additionally to two-dimensional pixel arrays – also a time-component – are not a subject of this Recommendation.

Both the source image and the reconstructed final image are presented by a color space which is encoded in an analogue signal form. Before an image compression algorithm, as described in T.80-Series Recommendations, can be applied, the image represented in analogue form must be converted (by sampling and quantization) to a digital form. The T.80-Series Recommendations compression schemes are concerned with the digital encoding/decoding of the image data only. The conversion process from analogue form into the digital form of data, and vice-versa, is outside of the scope of the compression schemes according to the T.80-Series Recommendations.

The nature of conversion (sampling and quantization) is strongly influenced by the type of source image to be compressed:

Note – In case of a scanned black/white document a bi-level (two-step) digital representation with a 50% gray-scale threshold is optimal from the storage point of view (1 bit/pixel in the uncompressed image). In case of a natural full-color image multi-level (usually 256) representation per color component is desirable to construct a true replica of the source image (usually 16-24 bits/pixel for the uncompressed image). The right selection of the quantization steps (often called precision) is outside of the scope of the techniques described in Recommendations T.81 and T.82. As a general guide-line, Recommendation T.81 is better suitable for multi-level continuous-tone images, and Recommendation T.82 for bi-level and/or limited multi-level images if lossy image compression is also sufficient . For lossless color images either Recommendation T.81 or T.82 can be applied. For bi-level lossless images only Recommendation T.82 is effective. The range of potential applicability of Recommendations T.81 and T.82 is illustrated for informational purposes in Figure 1/T.80.

Both algorithms shall be prepared for a flexible, sufficiently narrow or wide range of precisions defined and parameterized by any application. More details can be found in Recommendations T.81 and T.82.

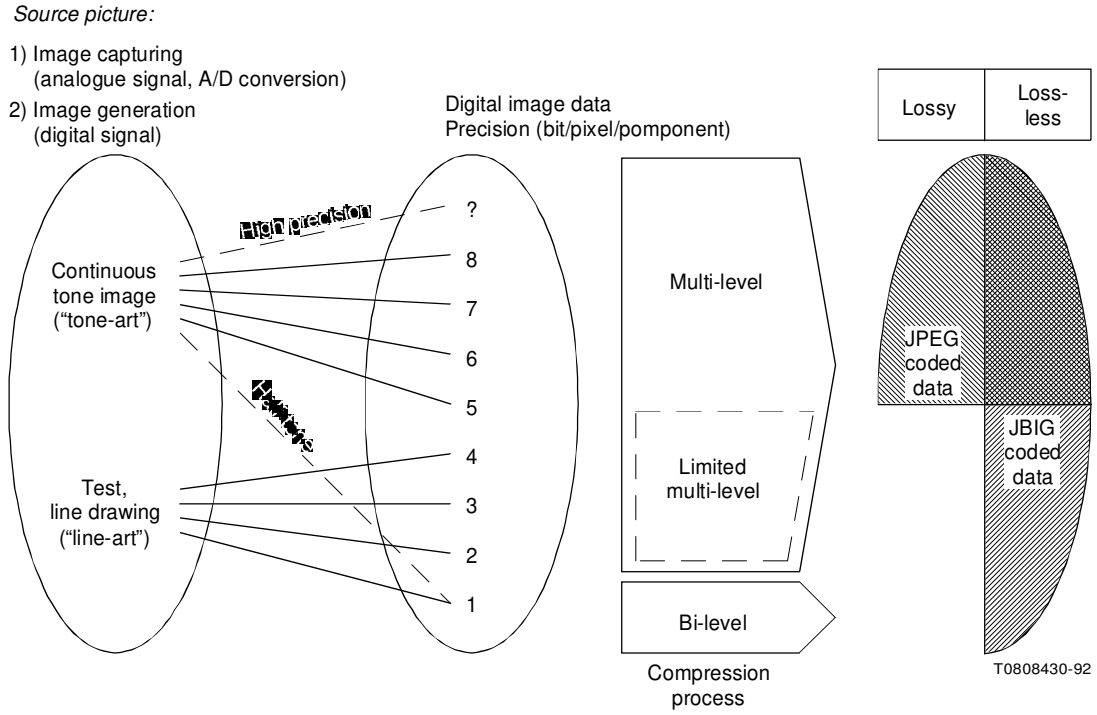

FIGURE 1/T.80

Typical application areas of T.81 and T.82 techniques with regard to the digital quantization/precision of data

5.2 *Image resolution, interleave*

The resolution of an image shall be defined by the number of horizontal and vertical pixels. Both in Recommendations T.81 and T.82 the actual number of resolution shall be a parameter for the compression scheme. The actual definition of image resolution is defined by the CCITT service/application using T.81 and/or T.82

techniques. The range of the image resolution parameters shall be sufficient large enough to incorporate realistic size of images. More details can be found in Recommendations T.81 and T.82.

The capability of interleave shall be supported to reduce the amount of data to code an image with high-fidelity. Interleave of color components result in different size of image resolutions for different color components. Sampling and actual resolutions of the individual color components are defined and controlled by the CCITT service/application using the compression techniques defined in Recommendations T.81 and T.82. T.81 and T.82 parametrization shall allow a great variety of interleave pattern. More details can be found in Recommendations T.81 and T.82.

5.3 *Support of dithering and halftoning*

Addaptive processing of halftone- and dither-images shall be supported by the T.80-Series Recommendations.

Note – This requirement is new. Existing image compression methods defined in Recommendations T.4 and T.6 are tuned for text and line drawings, but perform badly on half-tone- and dither-images.

5.4 *Lossy and lossless compression*

The T.80-Series Recommendations specifie two classes of encoding and decoding processes, lossy and lossless processes. It is up to the CCITT service/application to define whether an application requires lossless compression, or whether a lossy compression also satisfied the quality requirements of that application. The requirement for lossy and/or lossless coding shall be signalized to the appropriate T.80-Series Recommendations by the application.

Note – At this point in time, Recommendation T.81 supports both lossy and lossless coding, while Recommendation T.82 only lossless coding.

The lossless encoding/decoding process shall produce an image data stream that is identical to the data stream of the original image. Thus, the source and final images data stream have to be identical.

The lossy encoding/decoding process produces an image data stream that is different from the data stream of the original image. However, the subjective appearance of the final image shall be the same, or close to the original.

Note 1 – Based on the degree of lossyness, the appearance of the final image may vary between "subjectively identical" to the original and "noticeably different, but recognizable". The former is suitable for many applications and produces a better compression as with lossless compression. The later is suitable for the first scan of a progressive image, a small size of "icon type" image, or a low quality image (e.g. for data base searches).

Note 2 – There are certain applications, such as medical images, high quality prints, images for subsequent image processing that require lossless data compression/decompression. The compression ratio for lossless images is, however, noticeably lower than for the same lossy image. Therefore, usually, the image quality achieved by lossy encoding/decoding process is lower than for lossless images. Image quality enhancement by local picture processing is possible, but it is outside of the scope of the T.80-Series Recommendations.

Note 3 – The right selection of the lossy/lossless parameter significantly influences data compression, and thus, transmission time and/or storage requirements.

5.5 *Modes of operation*

T.80-Series Recommendations specifie two distinct modes of operation, sequential and progressive.

In a sequential encoding/decoding process, an image (or a color component of it) shall be processed from the top to the bottom. Depending on the compression technique applied, this can be done by entities of pixels, or by block of pixels, or by entire stripes of horizontal lines. The details are given in Recommendations T.81 and T.82. The sequential mode of operation may be either lossless or lossy.

Note – The "sequential mode of operation" – as described in this Recommendation is also defined in Recommendations T.81 and T.82 ("sequential behaviour").

Recommendation T.81 distinguishes between "sequential DCT-based" (lossy process) and "lossless" (DPCM-based) operation mode.

Recommendation T.82 defines a "single-progression sequential coding" operation mode that is compatible with the so-called "progressive-compatible" sequential coding (provided the number of differential layer is zero). An equivalent of this functionality is not defined/implemented in Recommendation T.81.

In a progressive encoding/decoding process an image shall be processed in their entire integrity step-by-step, whereby after a first lower quality image after each decoding step, the quality of the reconstructed image improves step-by-step, until the final image quality. There are progressive processes where this may produce either a lossless progressive final image (Rec. T.82) or a lossy progressive final image (Rec. T.81) only.

There are two distinct classes of progressive modes: *hierarchical* and *fixed-resolution* of progressive mode.

In the hierarchical progressive mode, after each progressive step the horizontal and vertical resolution of the image multiplies by a predefined factor (usually by 2).

Note – The "hierarchical progressive mode" – as defined in this Recommendation – is also defined in both Recommendations T.81 and T.82.

Recommendation T.81, however, does not label its "hierarchical mode" as a type of "progressive mode". In Recommendation T.81 the term "progressive" is left to what this Recommendation defines as the "fixed-resolution progressive mode".

Recommendation T.82, labels its "hierarchical mode" as "progressive mode", because at this point in time no other form of progressivity is defined in Recommendation T. 82.

In the fixed-resolution progressive mode, the resolution of the reconstructed image stays constant throughout the progressive build-up process.

Note – The "fixed-resolution progressive mode" – as defined in this Recommendation – is defined in Recommendation T.81, but not in Recommendation T.82.

Recommendation T.81 classifies its "fixed-resolution progressive mode" as "progressive DTC-based mode of operation".

The modes of operations are parameters of the compression techniques defined in Recommendations T.81 and T.82. Their selection is the task of the CCITT service/application referred to in Recommendations T.81 and T.82.

5.6 *Hardware and software requirements referred to in Recommendations T.81 and T.82*

The compression techniques defined in Recommendations T.81 and T.82 reflect a number of hardware and software requirements, which were established in order to allow a wide applicability of different algorithms:

- "Tool-kit" (Common Components) concept;
- "Symmetrical" encoding/decoding;
- "Parallel" encoding/decoding;
- Support of "Hard-copy and/or "Soft-copy" applications;
- Compression targets;
- Computational complexity, speed targets;
- Robustness of implementation.

5.6.1 *"Tool-kit" (Common components) concept*

Requirements are to be applicable to practically any kind of continuous-tone multi-level, limited-level, bi-level digital source images (i.e. for most practical purposes not to be restricted to images of certain dimensions, color spaces, pixel aspect ratios, etc.) and not to be limited to classes of imagery with restrictions on scene content (such as line drawing and/or text in case of Recommendations T.4 and T.6), including complexity, range of colors and statistical properties.

To achieve the above goal, the concept of using for image compression "Common components" from a "Tool-kit" shall be a basic requirement.

Note – Advantages:

– various requirements of different imaging applications can be satisfied in a flexible way;

– use of common hardware/software components when implementing imaging application, make implementation easier and more economical;

– easier harmonization of different imaging for CCITT and ISO/IEC applications;

– easier implementation of interworking among imaging applications;

Disadvantages:

– Imaging applications using Recommendation T.81 and/or T.82 are not necessarily compatible;

– the T.80-Series "Tool-kit; is flexible, but very comprehensive;

– the employment of the T.80-Series compression methods in concrete application (including selection of proper parameters, defining resolutions, color models, interleave structure, pixel aspect ratio, communication protocols for transmission, etc.) is still a major task.

5.6.2 *"Symmetrical" encoding/decoding*

The requirement of "symmetrical" encoding/decoding has two aspects: complexity of implementation, and "symmetricallity" in encoding/decoding time.

Note – In practice the first requirement is very difficult to specify. In order to satisfy all types of applications, the main goal is to design a process which has about the same complexity requirement for the encoder and the decoder. In contrast to this, there are other encoding processes in practice, where the encoding process is more complex than the decoding process. There is a similar requirement for the encoding/decoding time, which should be about the same.

5.6.3 *"Parallel" encoding/decoding*

The requirement of "parallel" encoding/decoding permits the start of decoding an image before the encoding process is finished.

5.6.4 *Support of "Hard-copy" and/or "Soft-copy" applications*

The requirement to support "Hard-copy" and "Soft-copy" applications is achieved, especially by supporting the "progressive" build-up mode of operation.

5.6.5 *Compression targets*

There are requirements to be at the state of the art with regard to compression rate and accompanying image fidelity, over a wide range of image quality ratings, in the range of "lossless" and in the "lossy" range where visual fidelity to the original is characterized as "excellent", "good" and "fair"; also the encoder should be parametrizable, so that the application (or user) can set the desired compression/quality tradeoff.

Note – For Recommendation T.81, the compression target was to compress a CCIR 601 4:2:2 continuous tone color image (source image precision: 16 bit/pixels) in "lossless" mode to about 8 bit/pixels, to an "excellent" quality "lossy" image with about 1.5 bit/pixel, to a "good" at about 0.75 bit/pixels and "fair" at 0.3 bit/pixels. It was a requirement, that there should be no significant difference between compression achieved by sequential and progressive build-up images.

For Recommendation T.82, the compression target was to be superior to the compression technique described in Recommendation T.6. (MMR encoding). On scanned bi-level images of text and line drawings, observed compression gain ranged between 1.1 to 1.5. On computer generated bi-level images, including text and line drawings, compression ratios as much as 1.2 to 1.6 times those obtained with MMR were observed. On images where multilevel grey or color tones were rendered using bi-level halftoning or dithering, observed compression ratios have been from 2 to 30 those obtained with MMR. There was a requirement, that there should be no significant difference between compression achieved by sequential and progressive build-up images.

5.6.6 *Computational complexity, speed targets*

There is a requirement to have traceable computational complexity to make feasible software implementations with viable performance on a range of CPUs, as well as hardware implementations with viable cost for applications requiring high performance.

The requirements for target speed is an encoding/decoding throughput of up to 64 kbit/s.

Note – Hardware tests have shown that VLSI implementations of T.81 and T.82 algorithms have practical complexity and have considerably higher data throughput than 64 kbit/s.

Software implementations of T.81 with CCIR 601 4:2:2 type images have shown that current "industry standard PCs" are able to provide a coding/decoding throughput of around 64 kbit/s. Software implementations of Recommendation T.82 are slower. Moderately higher speed is provided by using either optional templates optimized for software implementations or TP (typical prediction). Both techniques are described in Recommendation T.82.

5.6.7 *Robustness of implementation*

It is assumed that a given application using techniques defined in Recommendations T.81 and T.82 will use appropriate means to ensure the integrity of the compressed image data during transmission. Therefore, there is no requirement to implement error protection. Means shall, however, be provided to insert appropriate application marker codes into the compressed data stream, that provide aid to an underlying error correction mechanism.

Note – There was a general requirement that the compression schemes defined in Recommendations T.81 and T.82 be sufficiently robust, to allow possible minimal negative effects should data transmission error occur. In practice, however, the compression schemes defined in the Recommendations T.81 and T.82 are not robust enough to tolerate data transmission errors. Therefore, error-free communication channels shall be used.

References

[1] CCITT Recommendation T.4 (1989), *Standardization of group 3 facsimile apparatus for document transmission*.

[2] CCITT Recommendation T.6 (1989), *Facsimile coding schemes and coding control functions for group 4 facsimile apparatus*.

[3] CCIR Recommendation 601 (1990), *Encoding parameters of digital television for studios*.

[4] ISO/IEC 9281-1:1990, *Information technology – Picture coding methods – Part 1: Identification*.

[5] CCITT Recommendation T.101 (1993), *International interworking for videotex services*.