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Linzer et al.

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[54] **MULTIPLE RESOLUTION VIDEO COMPRESSION**

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[21] Appl. No.: **08/999,763**

[22] Filed: **Jul. 22, 1997**

Related U.S. Application Data

[63] Continuation of application No. 08/774,060, Dec. 23, 1996, abandoned.

[51] **Int. Cl.**[6] **H04N 7/50**

[52] **U.S. Cl.** **348/398**; 348/397; 348/399; 348/437; 348/438

[58] **Field of Search** 348/397–399, 348/387–389, 385, 438–439, 426, 441, 445–446, 448, 458–459, 408; 382/240; 386/111; 375/240; H04N 7/50

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Primary Examiner—Vu Le

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[57] **ABSTRACT**

An apparatus and method for compressing multiple resolution versions of a video signal are disclosed. A first resolution version of a video signal is applied to an input of a first video compressor and to an input of a video scaler. The first video compressor encodes the first resolution version of the video signal to generate a first compressed video bit stream. The video scaler generates a reduced resolution version of the video signal from the first resolution version. The reduced resolution version is supplied to a second video compressor and to the first video compressor. The first video compressor utilizes the reduced resolution version of the video signal in performing a hierarchical motion estimation (ME) search as part of the encoding process for the first resolution version. The second video compressor encodes the reduced resolution version to generate a second compressed bit stream. The second video compressor receives motion vectors or other results of the hierarchical ME search performed in the first video compressor, and uses these results to facilitate the encoding of the reduced resolution version. The apparatus and method may be used in a non-linear video editor, a video server or other video processing system. The video scaler and first and second video compressors may share memory, a transform unit and other processing hardware such that system cost and complexity are reduced.

30 Claims, 3 Drawing Sheets

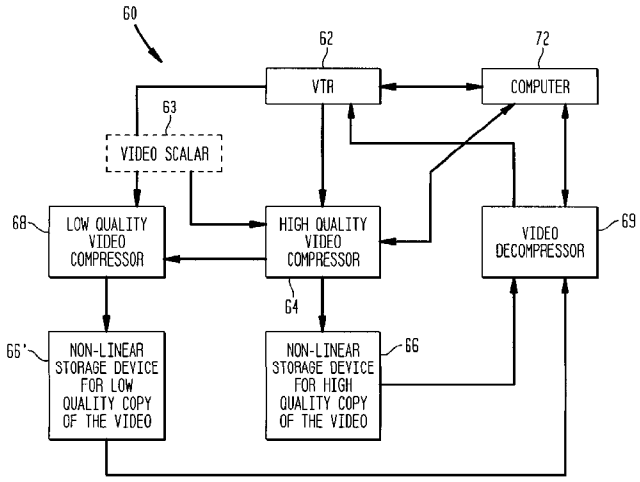


FIG. 1
(PRIOR ART)

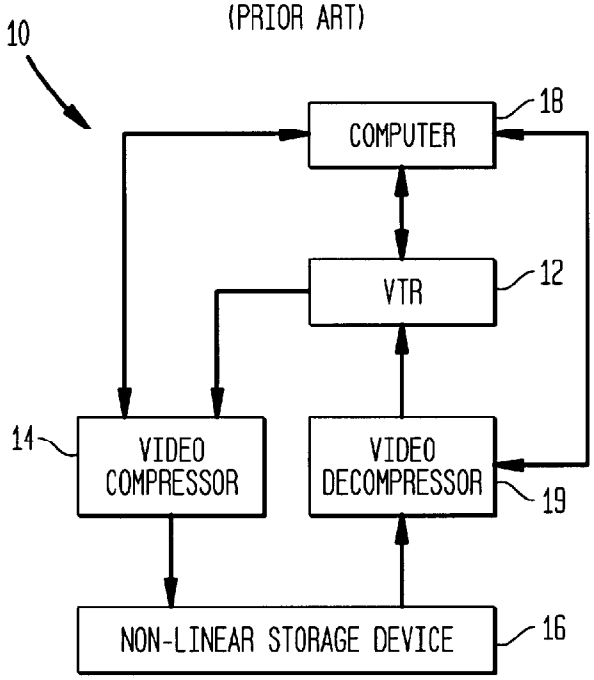


FIG. 2
(PRIOR ART)

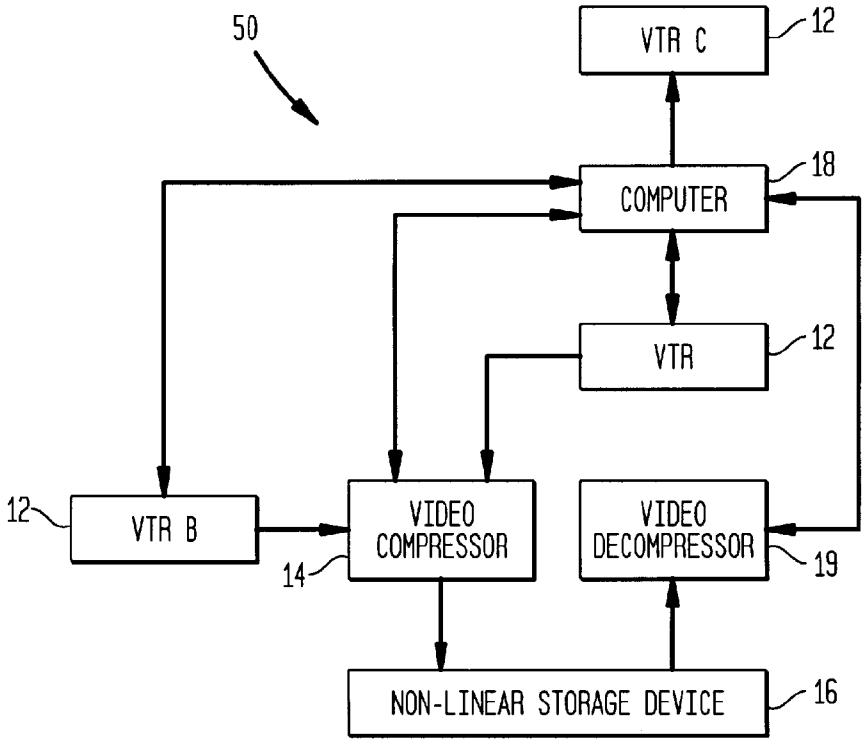


FIG. 3
(PRIOR ART)

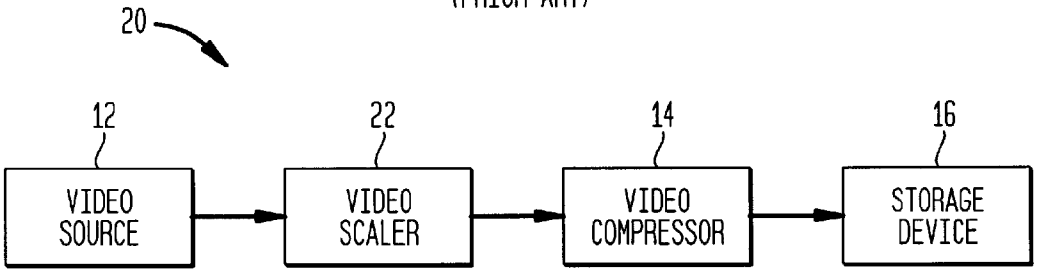


FIG. 4

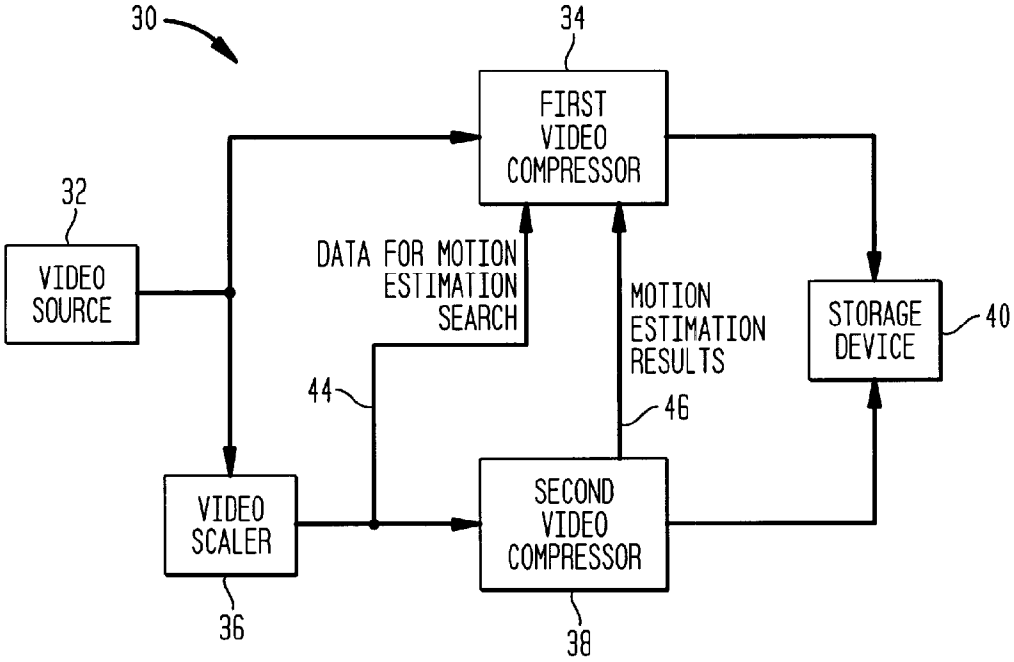


FIG. 5

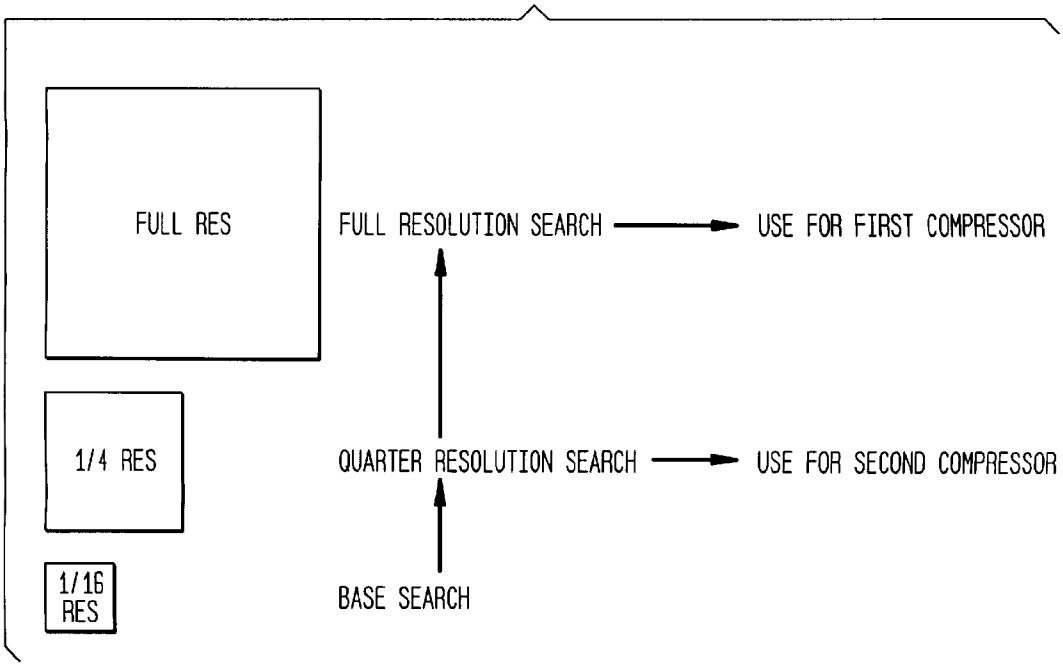
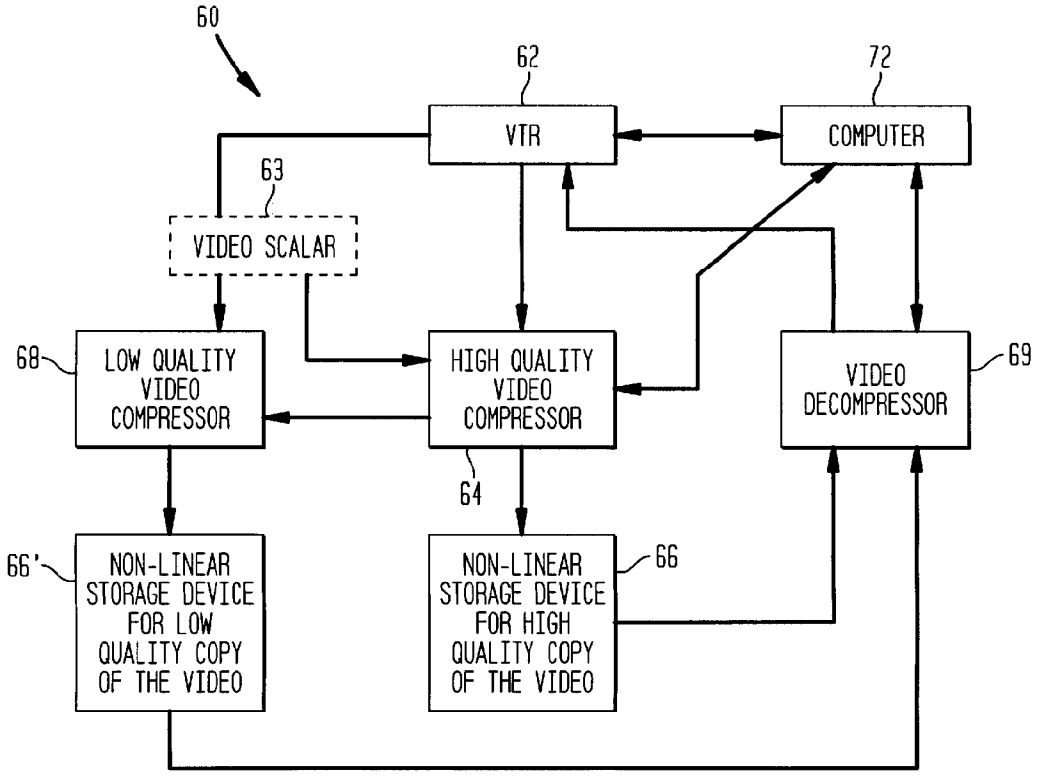

FULL RES
1/4 RES
1/16 RES
FULL RESOLUTION SEARCH
USE FOR FIRST COMPRESSOR
QUARTER RESOLUTION SEARCH
USE FOR SECOND COMPRESSOR
BASE SEARCH

FIG. 6


60
62
72
VTR
COMPUTER
63
VIDEO SCALAR
68
LOW QUALITY VIDEO COMPRESSOR
HIGH QUALITY VIDEO COMPRESSOR
VIDEO DECOMPRESSOR
69
64
66'
NON-LINEAR STORAGE DEVICE FOR LOW QUALITY COPY OF THE VIDEO
NON-LINEAR STORAGE DEVICE FOR HIGH QUALITY COPY OF THE VIDEO
66

MULTIPLE RESOLUTION VIDEO COMPRESSION

This is a continuation of Ser. No. 08/774,060 filed Dec. 23, 1996.

FIELD OF THE INVENTION

The present invention relates generally to digital video compression and more particularly to video compression methods and apparatus for producing different resolution compressed versions of a given video signal.

BACKGROUND OF THE INVENTION

FIG. **1** shows an "on-line" "non-linear" video editing system **10**. One or more linear video sources **12**, such as video tape recorders (VTRs), each output an analog or digital video signal to a compressor **14**. The compressor **14** compresses each video signal and stores the digital compressed video signals in a non-linear storage device **16**, such as a magnetic disk. Unlike the linear video signal source **12**, which accesses video signals sequentially, the non-linear storage device **16** supports random access of video signals. Compression of the video signals in the compressor **14** may be achieved according to the MPEG, MPEG-2, Dolby™ AC-3, etc., standards for compressing video and associated audio. See ISO/IEC IS 13818—1, 2, 3: Generic Coding of Moving Pictures and Associated Audio: Systems, Video and Audio. The compressed video signals are then edited using a computer **18** which accesses the compressed video signals for display and editing. In displaying a compressed video signal, the non-linear storage device **16** outputs a compressed video signal to a video decompressor **19**, which decompresses the video signal for display on a display monitor. After editing, the edited compressed video signal may be retrieved from the non-linear storage device **16** and decompressed by decompressor **19** for storage on a linear storage device (such as a VTR) or transmitted.

The non-linear video editing system **10** enables the operator to access the video in a random fashion instead of a sequential fashion. This facilitates the editing of the video and provides for rather precise editing. The editing is said to be "on-line" in that the final edited video event is incrementally constructed as the edits are made. For example, if the operator chooses to splice a first video clip to a second video clip, then the compressed form of the first video clip is spliced to the compressed form of the second video clip, at the time the operator makes such a choice to produce an edited compressed video signal. The edited video event is formed by decompressing the edited compressed video signal.

FIG. **2** shows a an "off-line" "non-linear" video editing system **50**. Multiple linear video sources **12** are used to input video signals to a video compressor **14**. The video compressor **14** compresses each video signal and stores the compressed video signal on a non-linear storage device **16**. As before, a computer **18** can access the compressed video signals on the non-linear storage device **16** for viewing and editing. The compressed video signals are decompressed in decompressor **19** prior to viewing on a display monitor (not shown).

Unlike the video editing system **10**, the video editing system **50** does not incrementally form the final edited video event as each edit decision is made. Rather, the formation of the final edited video event is deferred until the editing of the video signals is complete. The computer **18** generates a "edit decision list" as each editing operation is performed by the operator. Each edit decision on the edit decision list may, for example, indicate the kind of edit transition/operation to use (cut, fade, wipe dissolve, over-dub, etc.), which video clips are operated on by the edit operation and the edit points (e.g., specific pictures or audio frames at which the editing operation begins and ends) within those clips. The operator can preview a "facsimile" of the final event as formed by performing the edit operations indicated on the edit decision list on the compressed video signals stored in the non-linear storage device **16**. After the operator has approved the edit decisions, the computer **18** accesses the original video signals stored on the linear storage devices **12** and performs edit operations on these video signals according to the edit decision list.

Typically, an off-line video editor **50** produces a final edited video event with better video and audio quality than an on-line video editor **10**. This is because the video event produced by on-line video editing contains compression artifacts produced by the lossy or imperfect compression and decompression of the video. Nevertheless, an on-line video editor **10** is less expensive than an off-line video editor **50** because the on-line video editor **10** needs only a single linear storage device **12**. Furthermore, the linear storage device **12** used in the on-line video editor **10** need not be as sophisticated as the linear storage device **12** used in the off-line video editor **50** since it does not have to advance to multiple specific edit points (as would be necessary in the off-line video editor in forming the final edited video event from the edit list). The on-line video editor **10** is easier to use because the physical media (video tapes) on which the original video information is stored need not be resident in the linear storage device **12** to create the final edited video event. This is because once the video signals are transferred to the non-linear storage device **16**, the video signals need not be retrieved from the linear storage device again.

In order to reduce the level of compression artifacts present in the final edited video event in the on-line video editor **10**, the on-line video editor **10** may typically use high compression data rates, high resolution and/or inter-frame coding. Video signals from source **12** in system **10** are compressed before being stored in the storage device **16** in order to save disk space and because the throughput of inexpensive disk drives is generally insufficient to support uncompressed high resolution video. To insure sufficiently high quality edited video, a non-linear editor typically uses high resolutions such as 720×480 pixels at 30 frames/sec and high compressed bit rates such as 18–50 Mbits/sec.

The use of high resolutions, high bit rates and/or inter-frame encoding in the compressor **14** can increase the difficulty of processing functions such as accessing stored compressed video streams, playing back more than one bit stream at the same time, and decoding/decompressing with trick modes such as fast forward and fast reverse. A compression system which utilizes compressed video bit streams having low resolution, low bit rate and/or only intra-frame encoding does not suffer these drawbacks. It is therefore desirable in many applications to provide a system in which multiple resolution and/or multiple bit rate versions of a given video signal can be compressed and stored. The high resolutions, high bit rates and inter-frame encoding can then be utilized when necessary, while the advantages of low resolution, low bit rates and intra-frame encoding can also be provided in appropriate applications.

Video servers represent another application in which storage of multiple versions of compressed video bit streams is desirable. Such video servers are used to deliver video bit streams to end users over data communication networks. For

example, a World Wide Web server may be used to deliver video bit streams to different end users over different types of lines, including plain old telephone service (POTS) lines, integrated services digital network (ISDN) lines, T1 lines and the like. A version of a given compressed bit stream that may be suitable for a POTS user would be considered poor quality by a T1 user, and a bit stream suitable for a T1 user would be at too high a bit rate for a POTS user. It is therefore desirable for the video server to store a given video bit stream at multiple bit rates. The "optimal" resolution for a compressed video bit stream is the one that yields the best subjective video quality after decompression. This optimal resolution generally decreases with bit rate, such that it is desirable for the video server to compress the different bit rate streams at different resolutions.

FIG. **3** shows a conventional video compression system **20** which generates and stores multiple resolution versions of a given bit stream. The system **20** includes a video source **12**, video compressor **14** and storage device **16** which operate in the manner previously described in conjunction with FIGS. **1** and **2**. The system **20** also includes a video scaler **22** which receives a given video signal from the source **12** and generates a number of reduced resolution versions thereof. These reduced resolution versions are supplied to the video compressor **14**, which generates a compressed video bit stream at an appropriate bit rate for each of the reduced resolution versions of the video signal, and stores the resulting compressed streams on the storage device **16**.

The system **20** suffers from a number of significant problems. For example, each of the reduced resolution versions of a given video signal are separately and independently compressed. The information used to encode the video signal at one resolution is generally not used to facilitate the encoding process for the other reduced resolution versions. In addition, the video scaler **22** and video compressor **14** are not configured in a manner which enables them to share at least a portion of a common memory. The system **20** therefore requires relatively large amounts of memory. These and other drawbacks of the system **20** unduly increase its cost and complexity, and limit its usefulness in non-linear editor applications, video server applications and numerous other important video processing applications.

As is apparent from the above, there is a need for an improved multiple resolution video compression system in which hardware and processing resources can be shared to thereby significantly reduce the cost and complexity of the system.

SUMMARY OF THE INVENTION

The present invention provides an apparatus and method for compressing multiple resolution versions of a video signal. Each of the compressed version of the video signal may be independently decompressed, i.e., without resort to information contained in another version of the video signal.

Illustratively, such multiple compressed versions of the video signal may be used in a non-linear video editing system. One compressed version of the video signal may be used to determine how to edit the video to produce a final edited video event. A second compressed version of the video signal may be used to create the final edited video event. For example, a lower quality compressed version of the video signal may be viewed and used as a basis to form an edit decision list. After the edit decision list is complete, the actual editing operations may be performed on a higher quality compressed version of the video signal to produce a final edited high quality video event.

The invention permits the sharing of memory between a video scaler and video compressor in a video compression system, and the sharing of motion estimation, discrete cosine transform and other compression hardware between multiple video compressors in the video compression system. The invention thereby considerably reduces the cost and complexity of a video compression system. The invention also significantly improves the performance and capabilities of non-linear video editors, video servers and other video processing applications which utilize multiple resolution compression systems.

An exemplary embodiment of the invention includes first and second video compressors and a video scaler. A first resolution version of a video signal is applied to an input of a first video compressor and to an input of a video scaler. The first resolution version may be a CCIR601 image sequence or other high resolution unscaled video image sequence. The first video compressor encodes the first resolution version of the video signal to generate a first compressed video bit stream in accordance with MPEG-2 or another suitable video encoding standard. The video scaler generates a reduced resolution version of the video signal from the first resolution version. The reduced resolution version may be a QQCIF image sequence, a QCIF image sequence or a CIF image sequence, the images of which are $\frac{1}{64}$ size, $\frac{1}{16}$ size and $\frac{1}{4}$ size, respectively, relative to a full resolution CCIR601 image. Other types of images and image resolutions may also be used, and the video scaler may generate multiple reduced resolution versions of the video signal. The reduced resolution version or versions are supplied to a second video compressor and to the first video compressor. The first video compressor utilizes the reduced resolution versions of the video signal in performing a hierarchical motion estimation (ME) search as part of the encoding process for the first resolution version. The second video compressor encodes the reduced resolution version to generate a second compressed bit stream. The second video compressor receives motion vectors or other results of the hierarchical ME search performed in the first video compressor, and uses these results to facilitate the encoding of the reduced resolution version. Although some sharing of encoding information may occur during the compression, each video signal is independently decompressible without resort to information contained in the other video signal.

In accordance with other aspects of the invention, the video scaler and first video compressor may share a common memory for temporary storage of reduced resolution images, and the first and second compressors may be configured to utilize common motion estimation and discrete cosine transform hardware. For example, a single discrete cosine transform unit may be shared in a time multiplexed manner between the first and second video compressors.

According to another embodiment, a nonlinear editor is provided with first and second video compressors. The first video compressor is for compressing a first version of an input video signal to produce a low quality compressed video signal. The second video compressor is for compressing a second version of the same input video signal to produce a high quality compressed video signal, having a higher quality than the low quality compressed video signal. Each of the low quality and high quality compressed video signals produced by the first and second video compressors, respectively, are independently decompressible.

Illustratively, the low and high quality compressed video signals can be achieved a number of ways such as providing

different quality first and second versions of the input video signal for input to the first and second video compressors. For example, the first version may be one or more of the following: spatially scaled, temporally scaled, non-interlaced (progressive scanned or de-interlaced), or bit rate reduced, whereas the second version may be one or more of the following: full spatial resolution, full temporal resolution, interlaced, or full bit-rate. Alternatively, or in addition, the first and second video compressors can compress the first and second versions of the input video signal differently. For example, the first compressor may use one or more of the following: a less efficient compression standard, such as MPEG-1, intra-coding only, frame prediction only, or low bit rate coding whereas the second compressor may use one or more of the following: a highly efficient compression standard, such as MPEG-2, inter and intra-coding, field and frame prediction, or high bit rate coding.

Illustratively, the non-linear video editor includes a decoder which can simultaneously present more low quality compressed video signals than high quality compressed video signals in real time. Alternatively, or in addition, the non-linear video editor includes a computer that can perform more edits/effects (e.g., cuts, wipes, fades, dissolves, trick modes, etc.) on the low quality compressed video signals than on the high quality compressed video signals.

These and other features and advantages of the present invention will become more apparent from the accompanying drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a conventional off-line video editing system.

FIG. **2** shows a conventional on-line video editing system.

FIG. **3** shows a conventional video compression system.

FIG. **4** shows an exemplary video compression system suitable for providing multiple resolution compression in accordance with the present invention.

FIG. **5** shows a motion estimation strategy according to an embodiment of the present invention.

FIG. **6** shows a non-linear video editor according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is illustrated herein using an exemplary implementation of a multiple resolution video compression system particularly well-suited for use in applications such as "non-linear" video editors and video servers. It should be understood that the techniques of the present invention are more broadly applicable to any application in which it is desirable to generate multiple resolution versions of a given video signal. The invention is suitable for use with MPEG-2 encoding as well as other video encoding standards. The term "reduced resolution" as used herein is intended to include any version of a given video signal which has a lower resolution than an unscaled version of the given signal supplied from a video source. The reduced resolution may be a reduced luminance resolution or a reduced chrominance resolution or both.

FIG. **4** shows an exemplary embodiment of a multiple resolution video compression system **30** in accordance with the present invention. A video source **32** supplies a video signal to a first video compressor **34** and a video scaler **36**. The video source **32** may be a single video signal source such as a video camera or video cassette recorder or a multiple-signal source made up of a combination of various sources. The video scaler **36** scales the video signal to at least one reduced resolution and sends the resulting reduced resolution version or versions to a second video compressor **38**. The first video compressor **34** compresses the full resolution unscaled version of the video signal from source **32** and stores the resulting compressed video bit stream in the storage device **40**. The storage device **40** may be an optical or magnetic disk drive or disk array, an electronic memory or other suitable compressed video storage device. The second video compressor **38** compresses at least one reduced resolution version of the video signal to generate at least one corresponding reduced resolution compressed video bit stream. The compressed stream or streams from the second video compressor **38** are also stored in the storage device **40**. The compressed bit streams generated by the first and second video compressors **34, 38** may differ in bit rate, group of picture (GOP) structure and/or other parameters. The video scaler **36** and the video compressors **34, 38** may be combined into a single device to facilitate sharing of hardware resources as will be described in greater detail below.

At least one reduced resolution version of the video signal is supplied from the video scaler **36** via line **44** to the first video compressor **34**. The reduced resolution version is used in a hierarchical motion estimation (ME) search performed on frames of the unscaled full resolution video signal in the first video compressor **34**. The scaler **36** and first video compressor **34** can therefore share at least a portion of a common memory. The first video compressor **34** performs the hierarchical ME search and generates ME search results which are supplied via line **46** to the second video compressor **38**. The second video compressor **38** uses the ME search results from the first video compressor **34** in encoding the reduced resolution version supplied from the video scaler **36**. For example, the second video compressor **38** may utilize an average of motion vectors supplied from the first video compressor **34** or the actual motion vectors generated by a particular hierarchical ME search stage. One way in which the second video compressor **38** can use the results of one stage of the motion estimation is shown in FIG. **5**. For this example, it is assumed that the second video compressor **38** compresses video at ¼ the resolution of the first video compressor **34**. The full resolution video signal is decimated to ¼ and 1/16 resolutions. Hierarchical motion estimation is then used in compressing the video signals. In such a motion estimation, a zero centered search is conducted on the 1/16 resolution image. The results of the first search are used as a basis to perform a second search on the ¼ resolution image (e.g., in the local vicinity of one or more candidate motion vectors identified in the first search). The results of the second search may then be used as a basis for performing a search on the full resolution image. The results of the second search may also be used directly to generate motion vectors in the second video compressor **38**. The results of the third search on the full resolution image are used to generate motion vectors for the first video compressor **34**. The first and second compressors **34, 38** may share common video compression hardware. For example, a single discrete cosine transform (DCT) unit could be time multiplexed between the first and second compressors **34, 38**. Other types of video compression hardware which could be time multiplexed or otherwise shared between first and second compressors **34, 38** include the inverse DCT, quantizer, inverse quantizer, motion compensator, run-level encoder, variable length encoder and pre-processing filters.

An exemplary hierarchical ME technique suitable for use in the system **30** of FIG. **4** is described in U.S. patent

application Ser. No. 08/652,231 of John Ju filed on May 23, 1996 and entitled "Video Encoding With Multi-Stage Projection Motion Estimation," which is assigned to the present assignee and incorporated by reference herein. In accordance with that technique, the first video compressor **34** of system **30** may receive a video signal from source **32** in the form of a sequence of CCIR601 video images. For each CCIR601 image, the video scaler **36** generates first, second and third reduced resolution images which may be a QQCIF image, a QCIF image and a CIF image, respectively, which are 1/64 size, 1/16 size and 1/4 size, respectively, relative to the CCIR601 image. These reduced resolution images are supplied via line **44** to the first video compressor **34** as previously described. Alternatively, the video scaler **36** may generate only a subset of the reduced resolution versions of the signal from source **12**, with the remaining reduced resolution versions generated within the first video compressor **34**.

The video compressor **34** performs a first stage motion vector search on the 1/64 size QQCIF image using a (0,0) motion vector starting point and a first search range suitable for detecting global motion within the original CCIR601 image. Global motion refers generally to motion involving many objects in a given image, such as the motion produced by a panning or zooming operation. The first video compressor **34** then performs a second stage motion vector search on the 1/16 size QCIF image using the (0,0) starting point and a second smaller search range suitable for detecting local motion within the original CCIR601 image. Local motion refers generally to motion involving small and/or irregular movements of a particular object or objects in a given image. The first video compressor **34** then performs a third stage motion vector search on the 1/4 size CIF image using a starting point based on scaled versions of the motion vectors identified in the first and second stage searches, and a search range smaller than the first and second search ranges. The first video compressor **34** finally performs a fourth stage search on the original CCIR601 image or a reconstruction thereof using the motion vectors identified in the third search stage. A motion compensation type and a suitable set of motion vectors for the original CCIR601 image is determined based on the results of the fourth stage search. This motion compensation type and set of motion vectors may be supplied to the second video compressor **38** via line **46** and used in the encoding of one or more reduced resolution images. It should be noted that the present invention may utilize any of a number of other types of hierarchical ME search techniques.

The video compression system **30** of FIG. **4** is well-suited for use in video server applications. For example, a video server may utilize the first video compressor **34** to generate a high resolution, high bit rate, inter-frame encoded version of a given video signal for delivery over relatively high bandwidth ISDN or T1 connections, while the second video compressor **38** is used to generate a low resolution, low bit rate, intra-frame encoded version of the given video signal for delivery over relatively low bandwidth POTS connections.

The video compression system **30** of FIG. **4** is also well-suited for use in non-linear video editor applications. For example, a high resolution compressed bit stream generated by the first video compressor **34** and stored in storage device **40** could be used in the final edited video, with one or more reduced resolution bit streams generated by the second video compressor **38** used to provide trick mode playback, fast random access, multiple simultaneous stream playback and other functions which facilitate the editing process.

FIG. **6** shows a non-linear video editing system **60** according to another embodiment of the present invention. As shown, a linear-video source **62** outputs an original video signal to a first video compressor **64** and a second video compressor **68**. The first video compressor **64** produces a high quality compressed video bitstream and the second video compressor **68** produces a low quality compressed video bitstream. For purposes of this specification, a low-quality compressed bit stream is created by either compressing a version of the video signal that is of lower quality than the version of the video signal compressed by the second video compressor **68** or compressing a video signal using a less efficient compression technique. For example, the version of the video signal received at the first video compressor **64** may have a lower spatial resolution, a lower temporal resolution, or a lower bit rate, than the version of the original video signal received at the second video compressor. Likewise, the version of the original video signal received at the first video compressor **64** may be noninterlaced (i.e., progressive scanned or deinterlaced) whereas the version of the video signal received at the second video compressor **68** may be interlaced. An example of such a situation is where the version of the video signal received at the first video compressor **64** is SIF (352×240×29.97 frames per second) format and the version of the original video signal received at the second video compressor **68** is HHR (352×240×59.98 fields per second) format. Another example is where the first version of the video signal (fed to compressor **68**) has a bit rate of 5 mbits/sec and where the second version of the video signal (fed to compressor **64**) has a bit rate of 30 mbits/sec.

To produce a spatially or temporally scaled video bit stream for input to the first video compressor **64**, the original video signal may be first scaled by scaler **63**. The scaled video signal is inputted to the first video compressor **64** but the unscaled original video signal is inputted to the second video compressor **68**. Note, then, that the use of a video scaler **63** is only illustrative of the type of device which can be used to lower the quality of the compressed video signal produced by the first video compressor **64**. Video scaler **63** may be replaced with a de-interlacer, or some combination of the de-interlacer and the video scaler.

Alternatively, the video compressors **64** and **68** receive the same version of the input video signal, in which case, the video scaler **63** is absent. Rather, the video compressor **68** produces a lower quality compressed video signal because the video compressor **68** operates according to a less efficient compression standard (e.g. MPEG-1, motion JPEG, H.261, H.263), uses fewer compression options (i.e., users intra-coding only, uses frame prediction only, uses a smaller motion vector search range, etc.) or simply compresses the video to a lower bit rate than the second video compressor **64**. Alternatively, the video compressors **64** and **68** both receive different quality video signals and compress the video signals using different efficiency compression techniques.

Despite these differences between the low and high quality compressed video bit stream, the compressors **64** and **68** may optionally share compression results to improve performance. Nevertheless, each of the low quality and high quality compressed video bit streams is independently decompressible, i.e., without reliance on any information in the other compressed video bit stream. The high quality compressed version of the video signal is stored on a first non-linear storage device **66**. The low quality compressed version of the video signal is stored on a second non-linear storage device **66'**. Preferably, the first and second non-linear storage devices **66** and **66'** are a single non-linear storage

device. Also provided are a computer **72** for viewing and editing video signals and a decompressor **69** for decompressing the low and high quality compressed video signals stored in the non-linear storage devices **66** and **66'**. The computer **72** in FIG. **6** may be embodied as a general purpose workstation or a general purpose work station with additional hardware for performing video effects. The video compressors **64** and **68** and decompressor **69** may be embodied as discrete integrated circuits or as a single integrated circuit. The additional hardware for performing video effects may be embodied on the same integrated circuit as the video effects may be embodied on the same integrated circuit as the video decompressor **69**.

In operation, the operator views and edits the video as decompressed from the low quality compressed video signal. The operator may preview edits as performed on the low quality compressed video signal or the high quality compressed video signal. Preferably, however, the formation of the edited video event is deferred. Instead, a video edit decision list is constructed during the course of editing the video signals. After the operator is satisfied with the edit decisions, the high quality compressed video signal is edited according to the edit decision list. Afterwards, the edited video event in high quality compressed form is stored on the non-linear storage device **66**. This edited video event illustratively may be decompressed by decompressor **69** and transmitted or stored using on a linear storage device such as VTR 62.

In general, the low quality compressed video signal is easier to store, retrieve, decompress and manipulate (perform edit operations on) than the high quality compressed video signal. For example, it may be easier to play back simultaneously a large number of low quality (low bit rate) bit streams, to play back such bit streams in reverse order, to play back such bit streams in fast forward or fast-reverse, etc. It is also possible that the non-linear storage device **66**, computer **72** and/or decompressor **69** can only accommodate such operations/transitions on the high quality compressed video signal in non-real time. Note that it is possible to provide equipment which can support such real time operations and transitions on the high quality compressed video signal as well as the low quality compressed video signal. However, a savings can be achieved since less expensive/sophisticated non-linear storage devices **66** and **66'**, decompressors **69** and computers **72** can be used which need not support real-time operations/transitions on the high quality compressed video signal.

The video editor **60** provides several editing options not available in the conventional on-line video editor **10** of FIG. **1**. For instance, the operator can view video clips at a fast-forward or fast-reverse speed even though the equipment (e.g., non-linear storage device **66'**, decompressor **69**, computer **72**) might only accommodate such real-time operations for the low quality compressed video signal (and therefore is substantially less costly than equipment that can also perform such operations/transitions on the high quality compressed video signal). For the same reason, the operator can use substantially less expensive equipment to view multiple clips simultaneously.

Note also that if the low quality compressed video signal uses intra-frame coding whereas a high quality compressed video signal uses both intra-frame and inter-frame coding, then reverse direction viewing of low quality clips is substantially simpler. (This is because inter-frame encoded video includes pictures that are encoded using data in preceding and/or succeeding reference pictures as predictors. Such reference pictures may be located in the bit stream of the high quality compressed video signal in a different order than the order in which they are presented or displayed to facilitate forward direction decompression and presentation. However, this reordering in the bit stream renders reverse order decompression and presentation more difficult.) Decompressors **69** which support reverse order play back of inter-frame encoded video signals are substantially more complex and expensive than decompressors that do not provide such a feature for inter-frame encoded video. Thus, the editor **60** provides a low-cost solution for accommodating real-time reverse play back of video clips (albeit, using only the low quality compressed video signal).

Furthermore, note that the operator can easily preview several complex transitions on the low quality compressed video signal to determine which produces the best results. Such complex transitions might be possible in real-time, or in any event, using less time than performing such transitions on the high quality compressed video signal. In one manner of preview, the operator performs several real-time complex transitions on the low quality compressed video signal. The operator selects a desired complex transition and performs such a transition on the high quality compressed video signal. Illustratively, the equipment can only perform the complex transition on the high quality video signal in non-real-time. The computer **72** signals the storage device **66** to retrieve the appropriate portion(s) of the high-quality video signal and signals the decompressor **69** to decompress them. If necessary, the computer **72** performs the complex transition on the decompressed video signal. The edited video signal with the complex transition thus produced is compressed (using the high quality compressor **64**) and stored on the non-linear storage device **66**.

More generally stated, decompressor **69** of the video editor **60** may be able to decompress, simultaneously, in real-time, N low quality compressed bit streams (for simultaneous display), but to decompress simultaneously, in real-time, only M high quality compressed bit streams (for simultaneous display), where $N>M\geqq 0$. Likewise, the computer **72** and compressor **68** may be able to edit simultaneously, in particular, to simultaneously perform effects on, N low quality compressed bit streams, whereas the computer **72** and compressor **64** may be able to only edit simultaneously M high quality compressed bit streams, where $N>M\geqq 0$. For example, it is possible that N=3 low quality compressed bit streams could be viewed in real-time simultaneously, but only M=1 high quality compressed bit stream can be viewed in real-time. Alternatively, it is possible to edit/perform effects on N=2 low quality compressed bit streams in real-time, e.g., a dissolve of one low quality compressed bit stream into another, yet only be able to perform such effects on the high quality compressed bit stream in non-real-time. In yet another embodiment, the editor **60** can perform effects on N=3 low quality compressed bit streams in real-time, such as a dissolve of one low quality compressed bit stream into a second low quality compressed bit stream, with a third low quality compressed bit stream in a small "picture-in-picture" box. However, the editor **60** might only be able to perform effects on M=2 high quality compressed bit streams in real-time, e.g., the dissolve of a first high quality compressed bitstream into a second high quality compressed bitstream, but not simultaneously also provide a third high quality compressed bit stream in a picture-in-picture box. Each of these embodiments is desirable since more effects would be necessary for previewing, in low quality, edits/effects before finalizing, and performing, the finalized edit/effect in high quality.

The description of the architecture above assumes that the equipment (e.g., decompressor **69**, non-linear storage

devices **66** and **66'** and computer **72**) support full real time operations/transitions on low quality compressed video signals but only non-real time transitions/operations on the high quality compressed video signals. Of course, the same architecture can be used with more expensive equipment that can support all transitions/operations on the high quality compressed video signal.

The foregoing description is merely illustrative of the invention. Those having ordinary skill in the art may devise numerous alternative embodiments within the scope of the appended claims. For example, alternative embodiments of the invention may utilize any number of additional video sources **32**, video scalers **36** and video compressors **34**, **38** arranged to process any number of video signals to generate any number of corresponding compressed video bit streams. The compressed bit streams may be stored on a single storage device **40** as shown in FIG. **3** or on multiple storage devices.

The claimed invention is:

1. An apparatus for compressing a video signal, comprising:

a first video compressor having a first input connected to receive a first resolution version of the video signal, and an output corresponding to a first independently decompressible compressed bit stream generated from the first resolution version of the video signal;

a video scaler for generating a reduced resolution version of the video signal, wherein the reduced resolution version has a lower resolution than the first resolution version; and

a second video compressor having a first input connected to receive the reduced resolution version of the video signal from the video scaler, and an output corresponding to a second independently decompressible compressed bit stream generated from the reduced resolution version of the video signal, wherein the first independently decompressible compressed bit stream is decompressible into a displayable video signal without resort to information contained in, or extracted from, the second independently decompressible compressed bit stream, and wherein both the second video compressor and the first video compressor generate the first and second independently decompressible compressed bit streams using one of the same information generated by the video scaler or the same encoding choice selected in compressing the first resolution version of the video signal.

2. The apparatus of claim **1** wherein the first video compressor and the second video compressor share a common transform unit operative to perform transforms on regions of pixels for the first resolution version of the video signal and the reduced resolution version of the video signal in a time multiplexed manner in generating the respective first and second compressed bit streams.

3. The apparatus of claim **1** wherein the first video compressor has a second input connected to receive the reduced resolution version of the video signal from the video scaler, wherein the first video compressor utilizes the reduced resolution version to perform a hierarchical motion estimation search in generating the first compressed bit stream from the first resolution version.

4. The apparatus of claim **1** wherein the second video compressor has a second input connected to receive results of a hierarchical motion estimation search performed in generating the first compressed bit stream from the first resolution version.

5. The apparatus of claim **4** wherein the second video compressor receives average motion vectors generated during the hierarchical motion estimation search.

6. The apparatus of claim **4** wherein the second video compressor receives one or more motion vectors generated by a particular stage of the hierarchical motion estimation search.

7. The apparatus of claim **1** wherein the first resolution version of the video signal includes a CCIR601 image sequence.

8. The apparatus of claim **7** wherein the video scaler generates at least one of first, second and third reduced resolution versions of the video signal including a QQCIF image sequence, a QCIF image sequence and a CIF image sequence.

9. The apparatus of claim **1** wherein said first resolution version of said video signal is interlaced and said second resolution version of said video signal is non-interlaced.

10. The apparatus of claim **1** wherein said first compressed bit stream is an MPEG-2 bitstream and said second compressed bit stream is an MPEG-1 bit stream.

11. The apparatus of claim **1** wherein the first video compressor generates the first independently decompressible compressed bit stream without any information outputted from the second video compressor.

12. A method of compressing a video signal, comprising:

compressing a first resolution version of a video signal to generate a first independently decompressible compressed bit stream;

scaling the video signal to generate a reduced resolution version of the video signal having a resolution lower than that of the first resolution version; and

compressing the reduced resolution version of the video signal to generate a second independently decompressible compressed bit stream, wherein the first independently decompressible compressed bit stream is decompressible into a displayable video signal without resort to information contained in, or extracted from, the second independently decompressible compressed bit stream, and wherein both the step of compressing the first resolution version of the video signal and the step of compressing the second resolution version of the video signal generate the first and second independently decompressible compressed bit streams using one of the same information generated during the step of scaling or the same encoding choice selected in the step of compressing the first resolution version of the video signal.

13. The method of claim **12** wherein the steps of compressing the first resolution version and compressing the reduced resolution version utilize a common transform unit to perform transforms on regions of pixels of the first resolution version and the reduced resolution version in a time multiplexed manner.

14. The method of claim **12** wherein the step of compressing a first resolution version of a video signal to generate a first compressed bit stream further includes the step of utilizing the reduced resolution version of the video signal generated in the scaling step to perform a hierarchical motion estimation search on the first resolution version of the video signal.

15. The method of claim **12** wherein the step of compressing the reduced resolution version of the video signal further includes the step of utilizing the results of a hierarchical motion estimation search performed in the step of compressing the first resolution version of the video signal.

16. The method of claim **15** wherein the results of the hierarchical motion estimation search include average motion vectors generated during the hierarchical motion estimation search.

17. The method of claim 15 wherein the results of the hierarchical motion estimation search include motion vectors generated by a particular stage of the hierarchical motion estimation search.

18. The method of claim 15 wherein the first resolution version of the video signal includes a CCIR601 image sequence.

19. The method of claim 18 wherein the reduced resolution version of the video signal includes at least one of first, second and third reduced resolution versions of the video signal including a QQCIF image sequence, a QCIF image sequence and a CIF image sequence.

20. The method of claim 12 wherein said first resolution version of said video signal is interlaced and said second resolution version of said video signal is non-interlaced.

21. The method of claim 12 wherein said first compressed bit stream is an MPEG-2 bitstream and said second compressed bit stream is an MPEG-1 bit stream.

22. The method of claim 12 wherein the first independently decompressible compressed bit stream is generated without any information generated during the step of compressing the reduced resolution version of the video signal.

23. An apparatus for compressing a video signal, comprising:

a first video compressor having a first input connected to receive a first resolution version of the video signal, and an output corresponding to a first independently decompressible compressed bit stream generated from the first resolution version of the video signal;

a video scaler for generating a reduced resolution version of the video signal, wherein the reduced resolution version has a lower resolution than the first resolution version; and

a second video compressor having a first input connected to receive the reduced resolution version of the video signal from the video scaler, and an output corresponding to a second independently decompressible compressed bit stream generated from the reduced resolution version of the video signal;

wherein the first video compressor and the second video compressor share a common transform unit operative to perform transforms on regions of pixels for the first resolution version of the video signal and the reduced resolution version of the video signal in a time multiplexed manner in generating the respective first and second compressed bit streams.

24. An apparatus for compressing a video signal, comprising:

a first video compressor having a first input connected to receive a first resolution version of the video signal, and an output corresponding to a first independently decompressible compressed bit stream generated from the first resolution version of the video signal;

a video scaler for generating a reduced resolution version of the video signal, wherein the reduced resolution version has a lower resolution than the first resolution version; and

a second video compressor having a first input connected to receive the reduced resolution version of the video signal from the video scaler, and an output corresponding to a second independently decompressible compressed bit stream generated from the reduced resolution version of the video signal;

wherein the second video compressor has a second input connected to receive results of a hierarchical motion estimation search performed in generating the first compressed bit stream from the first resolution version.

25. The apparatus of claim 24 wherein the second video compressor receives average motion vectors generated during the hierarchical motion estimation search.

26. The apparatus of claim 24 wherein the second video compressor receives one or more motion vectors generated by a particular stage of the hierarchical motion estimation search.

27. A method of compressing a video signal, comprising:

compressing a first resolution version of a video signal to generate a first independently decompressible compressed bit stream;

scaling the video signal to generate a reduced resolution version of the video signal having a resolution lower than that of the first resolution version; and

compressing the reduced resolution version of the video signal to generate a second independently decompressible compressed bit stream;

wherein the steps of compressing the first resolution version and compressing the reduced resolution version utilize a common transform unit to perform transforms on regions of pixels of the first resolution version and the reduced resolution version in a time multiplexed manner.

28. A method of compressing a video signal, comprising:

compressing a first resolution version of a video signal to generate a first independently decompressible compressed bit stream;

scaling the video signal to generate a reduced resolution version of the video signal having a resolution lower than that of the first resolution version; and

compressing the reduced resolution version of the video signal to generate a second independently decompressible compressed bit stream;

wherein the step of compressing the reduced resolution version of the video signal further includes the step of utilizing the results of a hierarchical motion estimation search performed in the step of compressing the first resolution version of the video signal.

29. The method of claim 28 wherein the results of the hierarchical motion estimation search include average motion vectors generated during the hierarchical motion estimation search.

30. The method of claim 28 wherein the results of the hierarchical motion estimation search include motion vectors generated by a particular stage of the hierarchical motion estimation search.

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