US 20250254280A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2025/0254280 A1**

SCHWARZ et al. (43) **Pub. Date: Aug. 7, 2025**

(54) **MULTI-VIEW CODING WITH EFFICIENT RESIDUAL HANDLING**

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(21) Appl. No.: **19/051,319**

(22) Filed: **Feb. 12, 2025**

Related U.S. Application Data

(63) Continuation of application No. 17/531,478, filed on Nov. 19, 2021, now Pat. No. 12,231,608, which is a continuation of application No. 16/848,297, filed on Apr. 14, 2020, now Pat. No. 11,184,600, which is a continuation of application No. 14/277,850, filed on May 15, 2014, now Pat. No. 10,659,754, which is a continuation of application No. PCT/EP2012/072889, filed on Nov. 16, 2012.

(60) Provisional application No. 61/561,452, filed on Nov. 18, 2011.

Publication Classification

(51) **Int. Cl.**

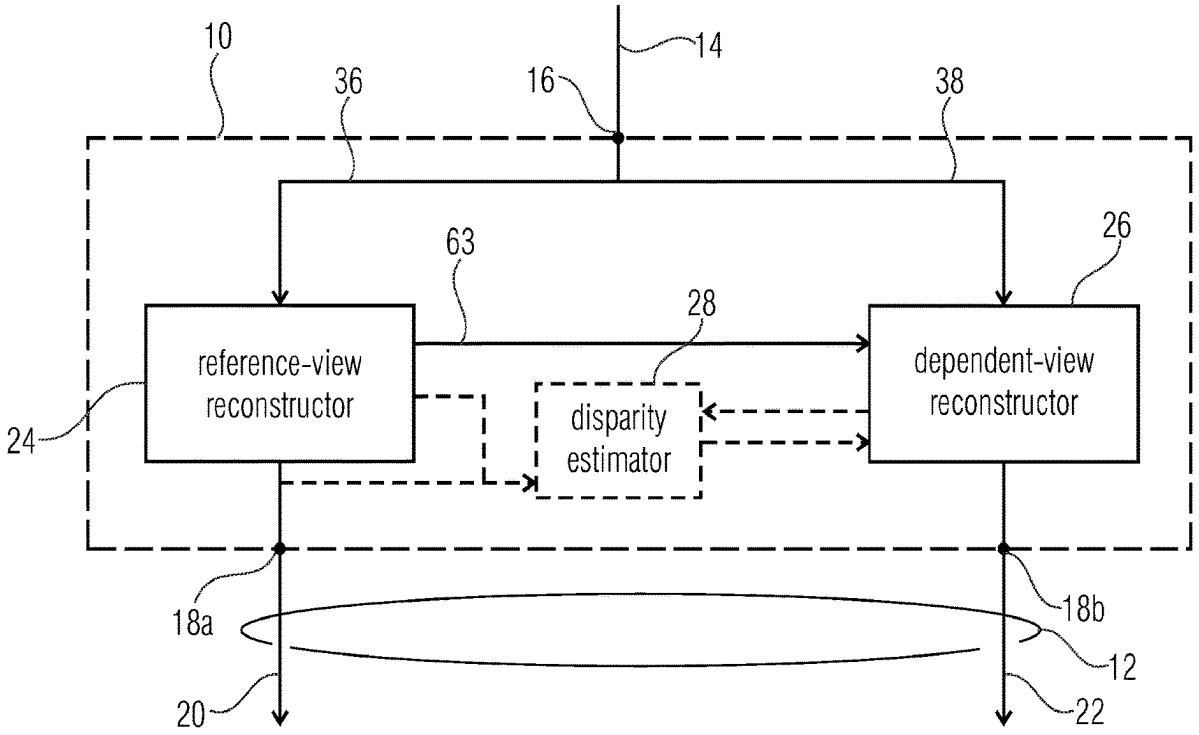
H04N 13/128	(2018.01)
H04N 13/161	(2018.01)
H04N 19/463	(2014.01)
H04N 19/597	(2014.01)

(52) **U.S. Cl.**

CPC ***H04N 13/128*** (2018.05); ***H04N 13/161*** (2018.05); ***H04N 19/463*** (2014.11); ***H04N 19/597*** (2014.11); *H04N 2213/003* (2013.01)

(57) **ABSTRACT**

A gain in multi-view coding is achieved as follows: the residual signal involved with coding a dependent view of the multi-view signal is predicted from a reference residual signal of the current picture of the reference view using block-granular disparity-compensated prediction, i.e. using disparity compensated prediction with a disparity defined at, and varying with, block granularity so that each block of the current picture of the dependent view has its own disparity displacement such as its own disparity vector, associated therewith. In other words, a remaining similarity between the residual signal involved with predictively coding the reference view is used in order to predict the residual signal involved with predictively coding the dependent view.



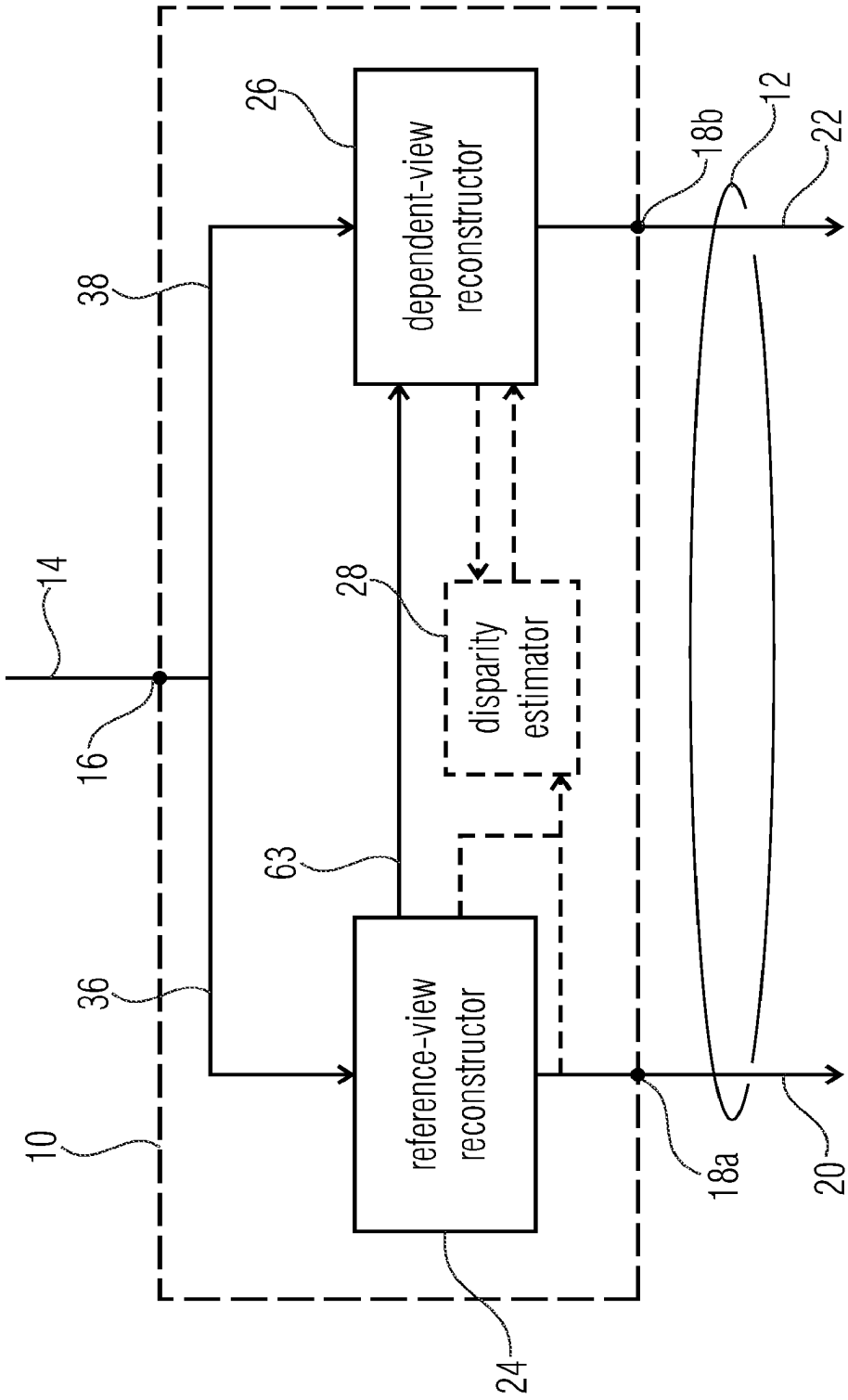

dependent-view reconstructor
reference-view reconstructor
disparity estimator
10
12
14
16
18a
18b
20
22
24
26
28
36
38
63

FIG 1A

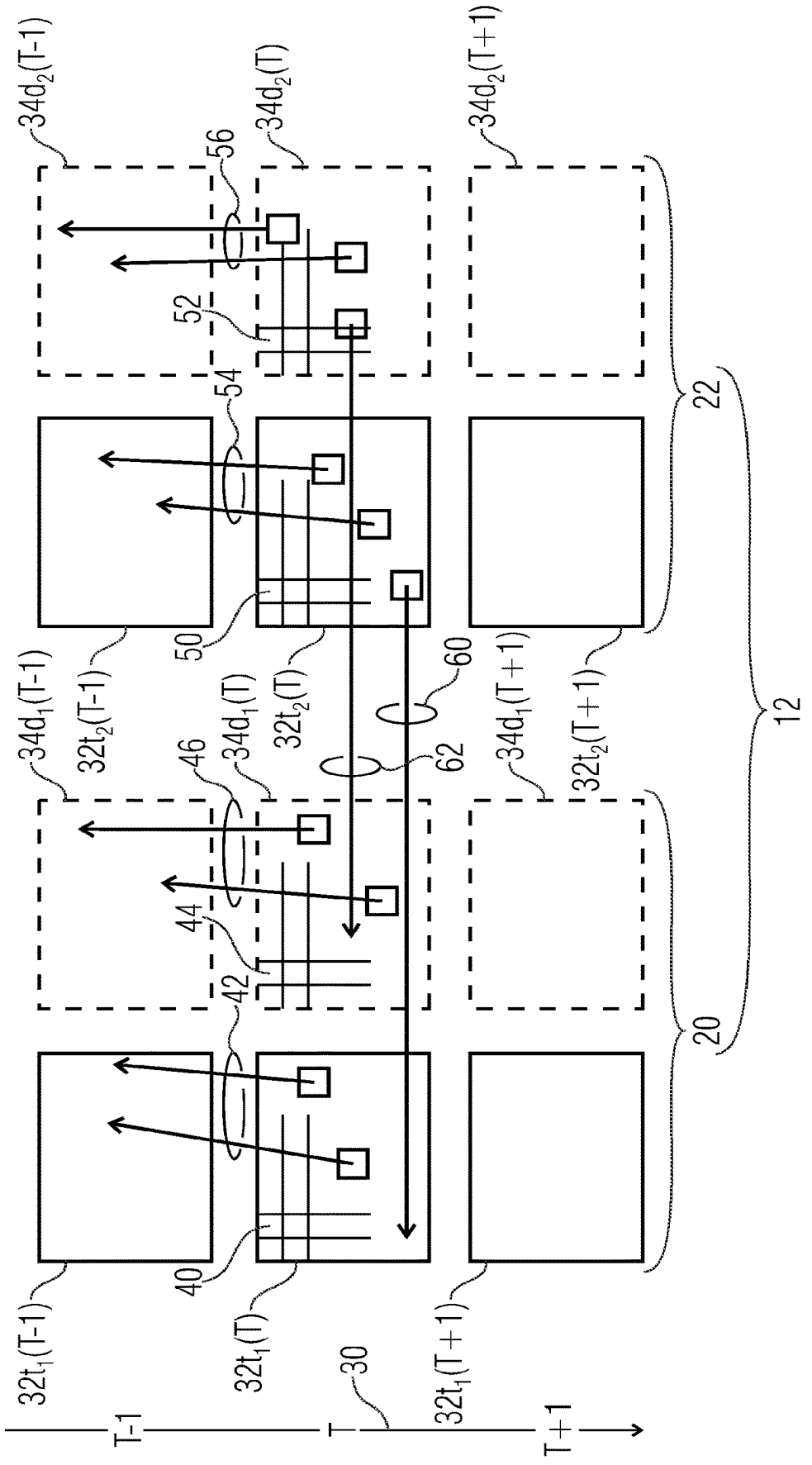

34d2(T-1)
34d2(T)
34d2(T+1)
56
52
54
50
34d1(T-1)
32t2(T-1)
34d1(T)
32t2(T)
34d1(T+1)
32t2(T+1)
60
62
46
44
42
40
32t1(T-1)
32t1(T)
32t1(T+1)
30
22
20
12
T-1
T
T+1

FIG 1B

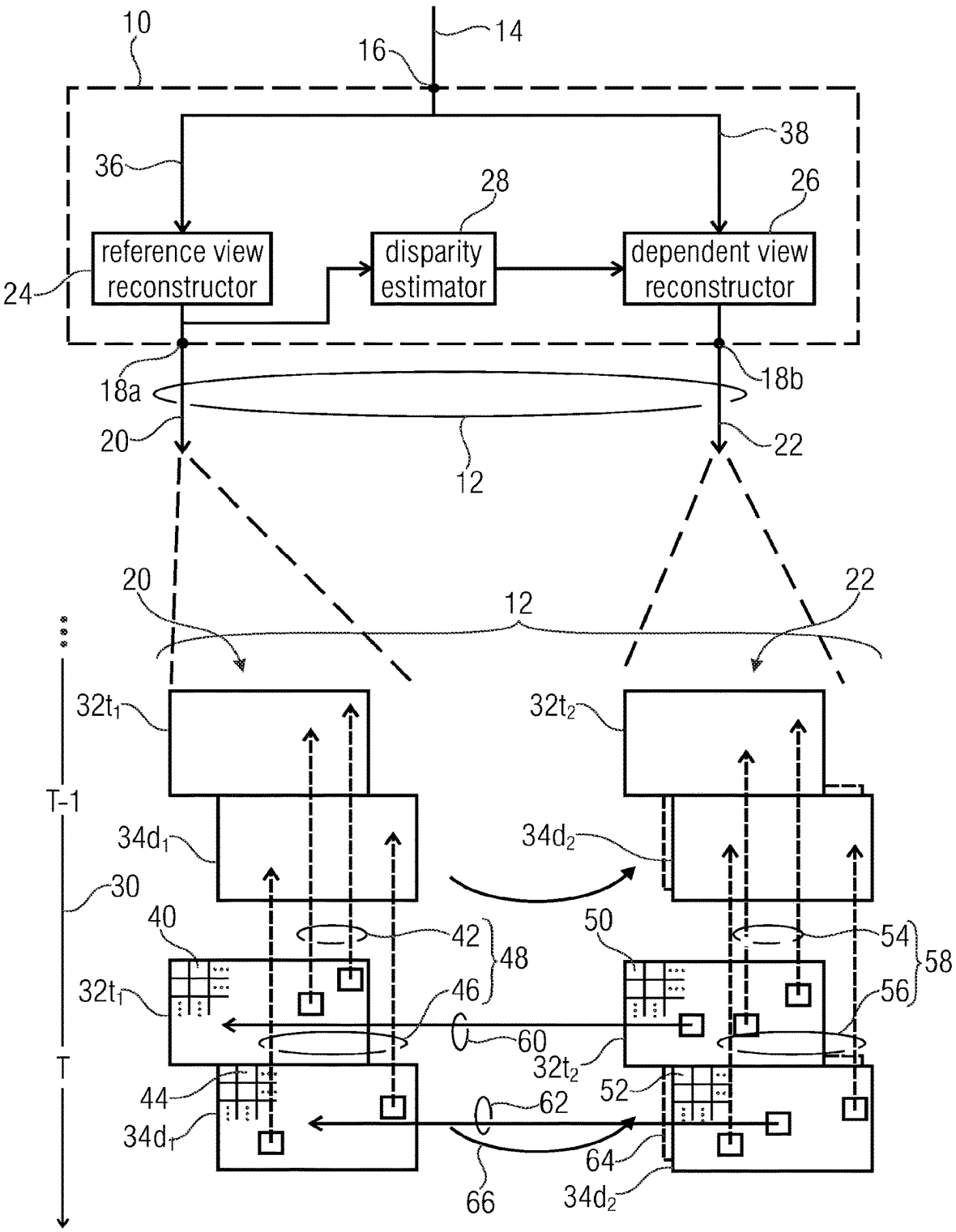

10
16
14
38
36
28
26
reference view reconstructor
disparity estimator
dependent view reconstructor
24
18a
18b
20
22
12
20
12
22
T-1
T
32t1
32t2
34d1
34d2
30
40
42
48
50
54
58
32t1
46
56
60
32t2
44
62
52
34d1
64
66
34d2

FIG 1C

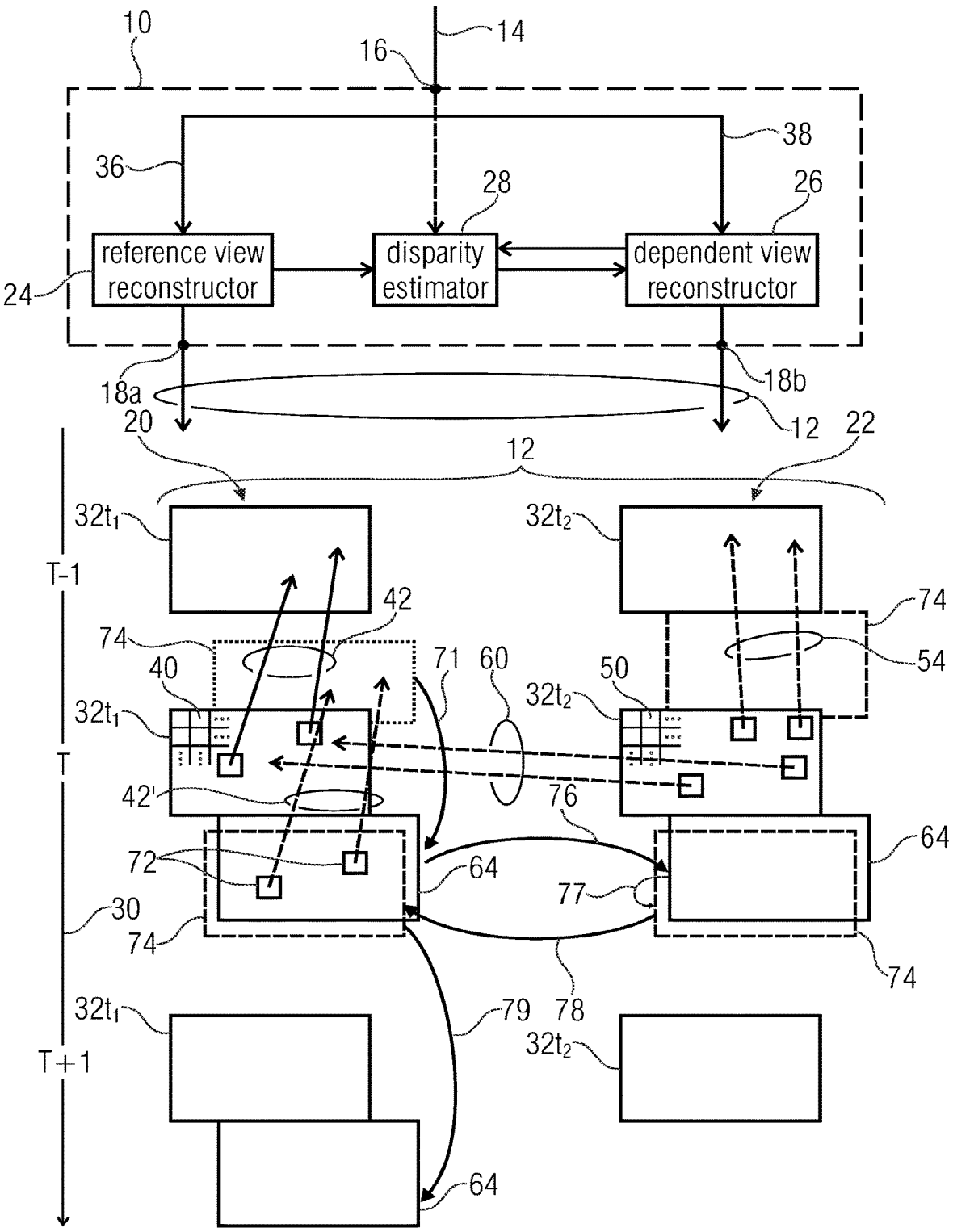

10
14
16
38
36
28
26
reference view reconstructor
disparity estimator
dependent view reconstructor
24
18a
18b
20
12
22
12
32t1
32t2
T-1
42
74
74
54
40
71
60
50
32t1
32t2
T
42'
76
72
64
64
77
30
74
74
32t1
79
78
32t2
T+1
64

FIG 1D

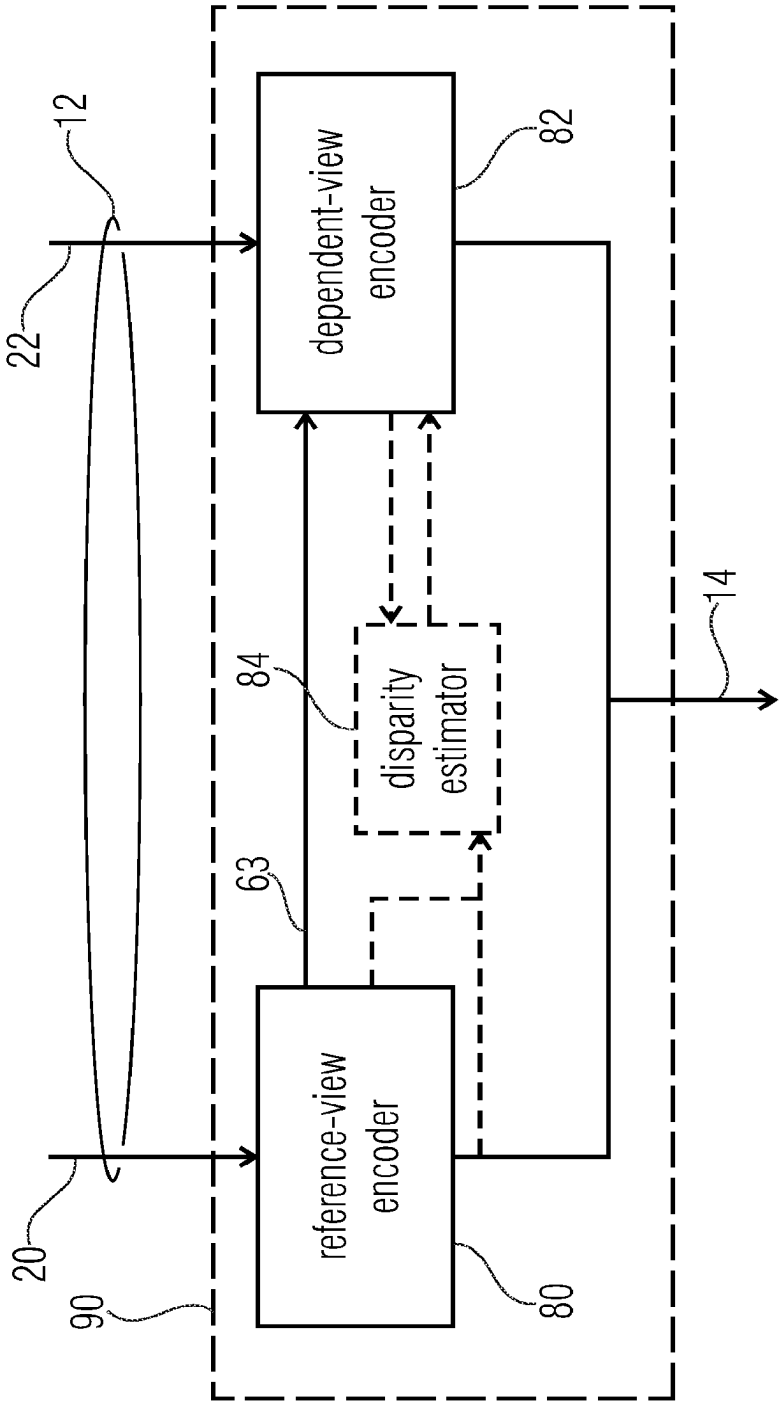

12
22
dependent-view encoder
82
84
disparity estimator
14
63
20
90
reference-view encoder
80

FIG 2

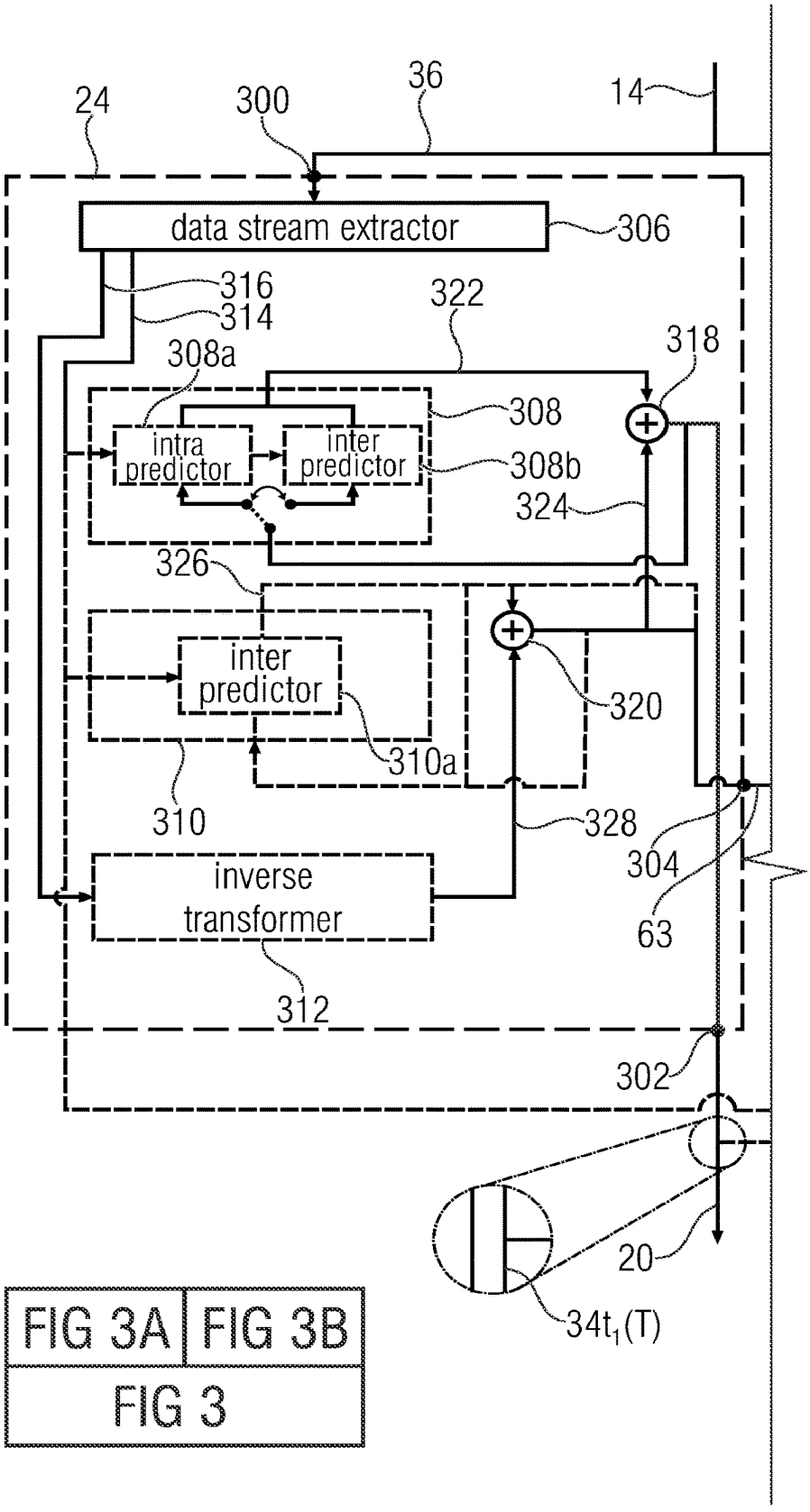


FIG 3A | FIG 3B

FIG 3

FIG 3A

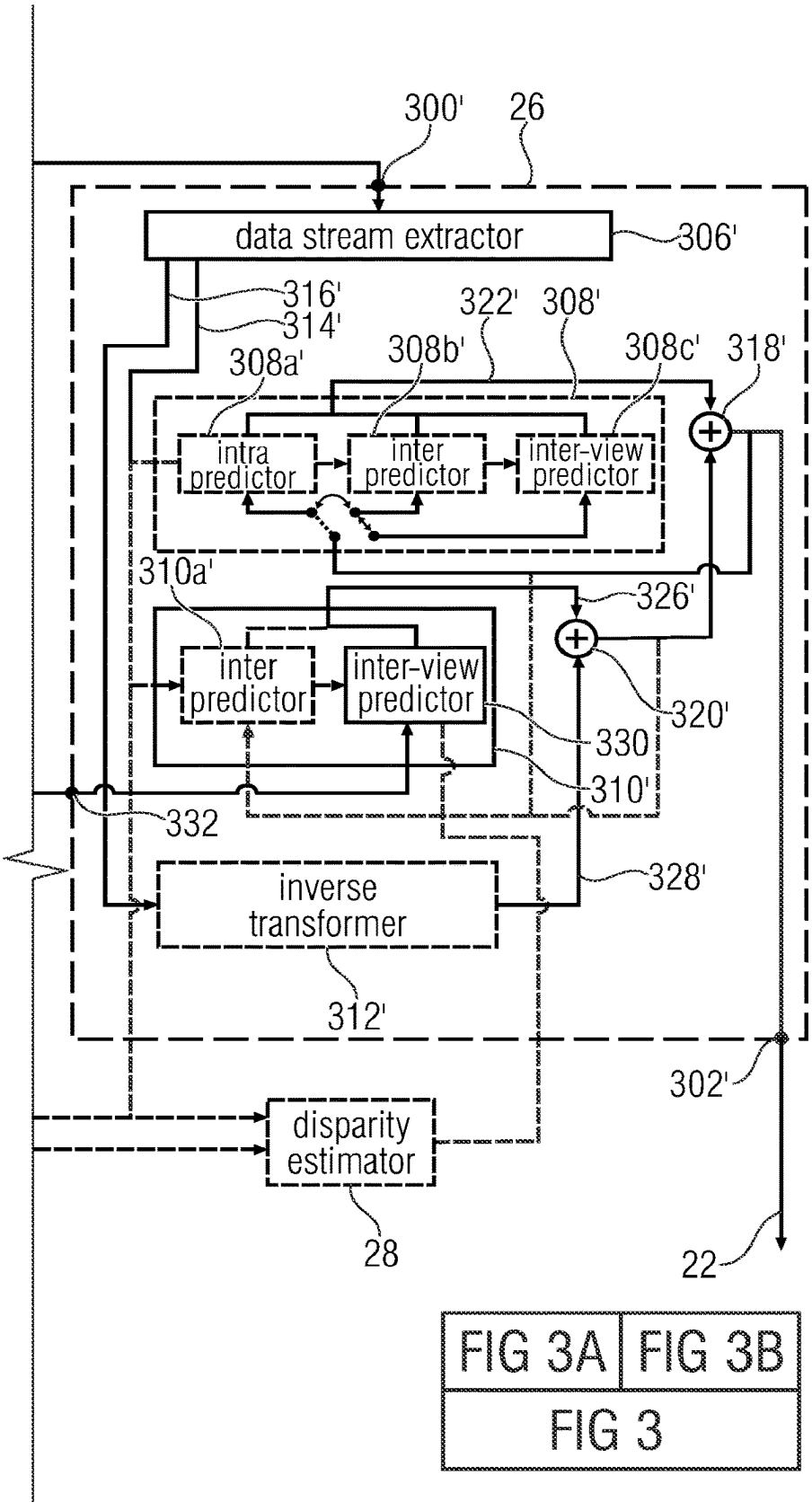


FIG 3A | FIG 3B

FIG 3

FIG 3B

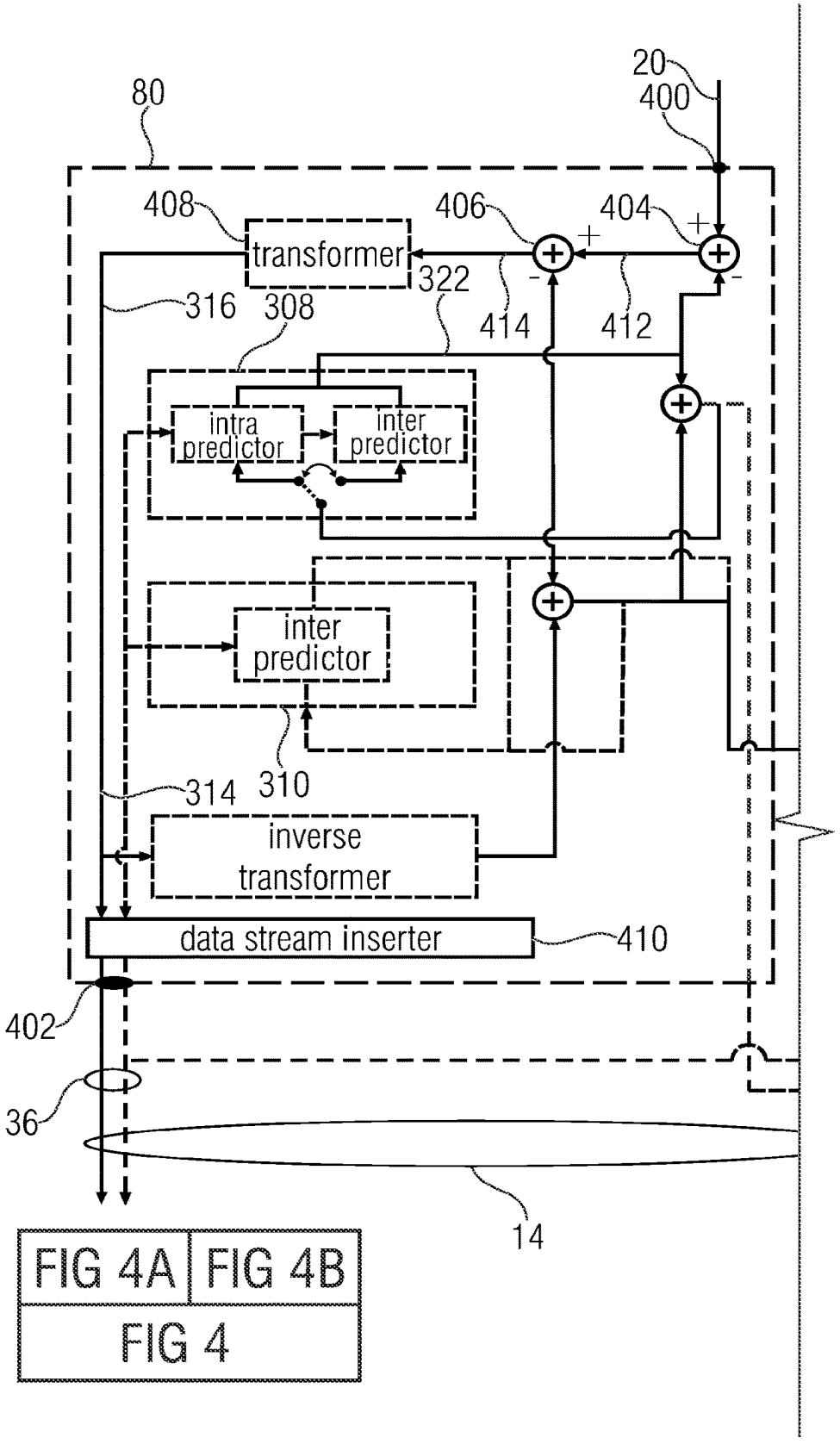


FIG 4A | FIG 4B

FIG 4

FIG 4A

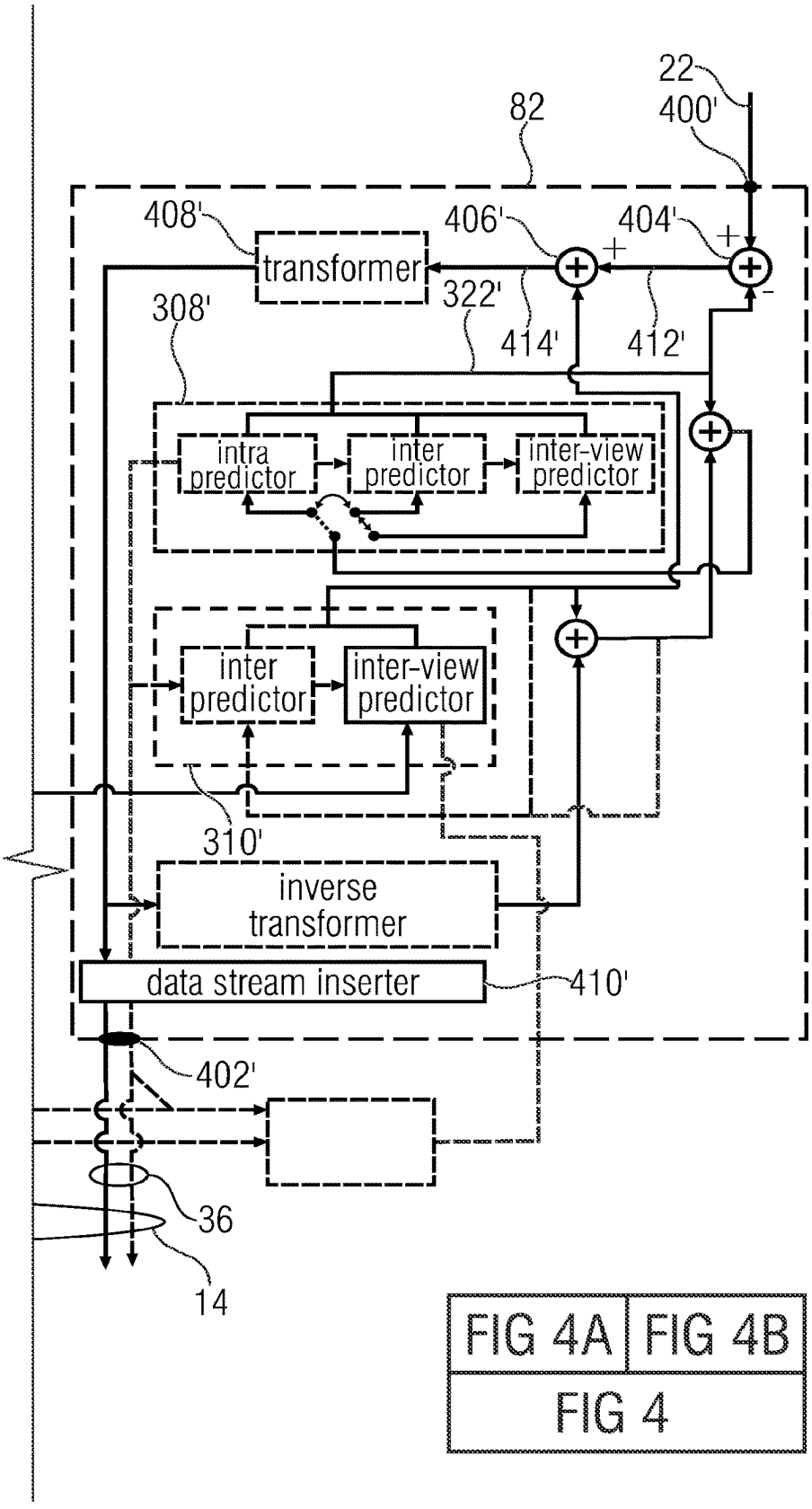


FIG 4A | FIG 4B

FIG 4

FIG 4B

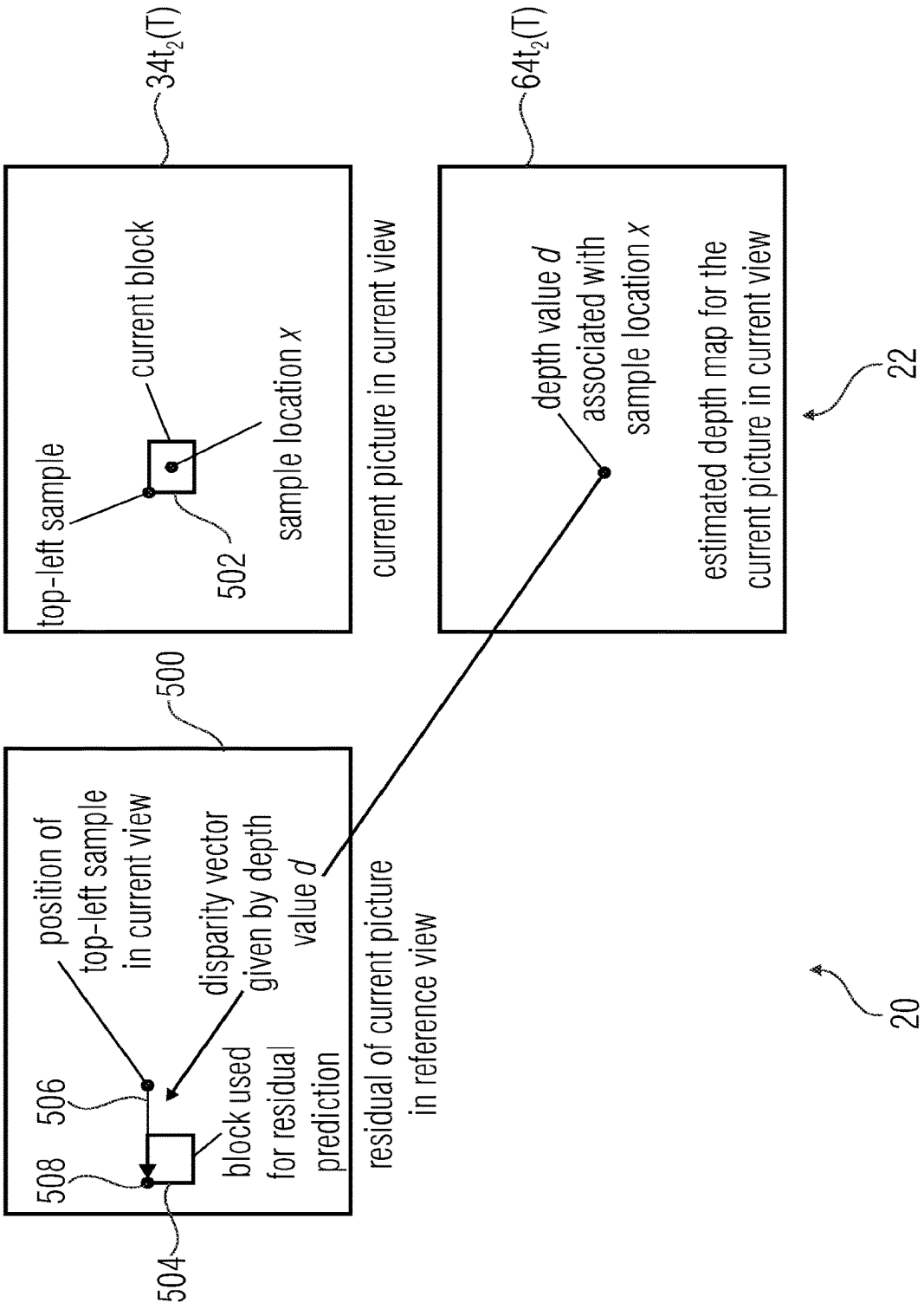

$34t_2(T)$
top-left sample
current block
sample location x
502
current picture in current view
$64t_2(T)$
depth value d associated with sample location x
estimated depth map for the current picture in current view
22
500
position of top-left sample in current view
disparity vector given by depth value d
506
508
block used for residual prediction
residual of current picture in reference view
504
20

FIG 5A

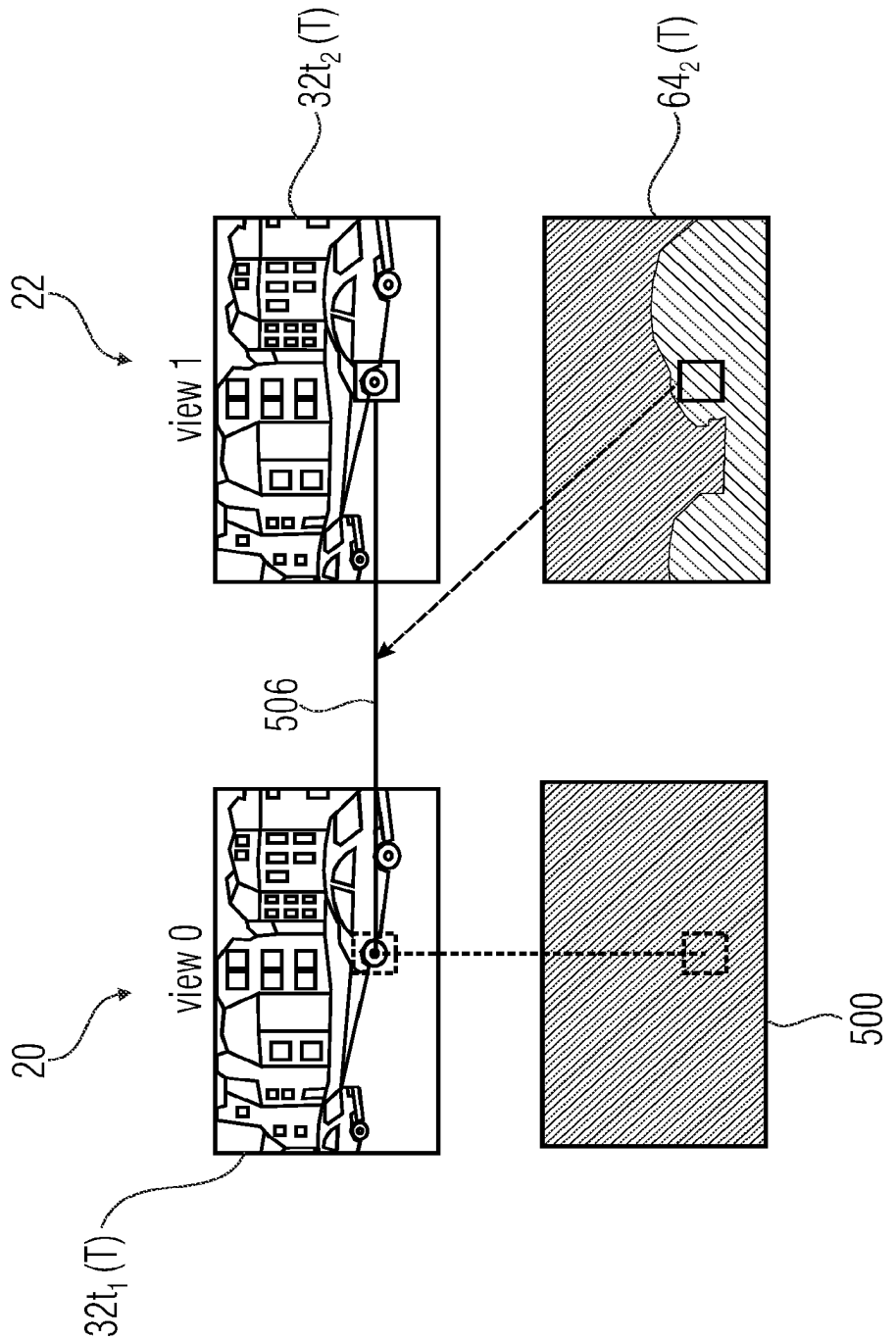


FIG 5B

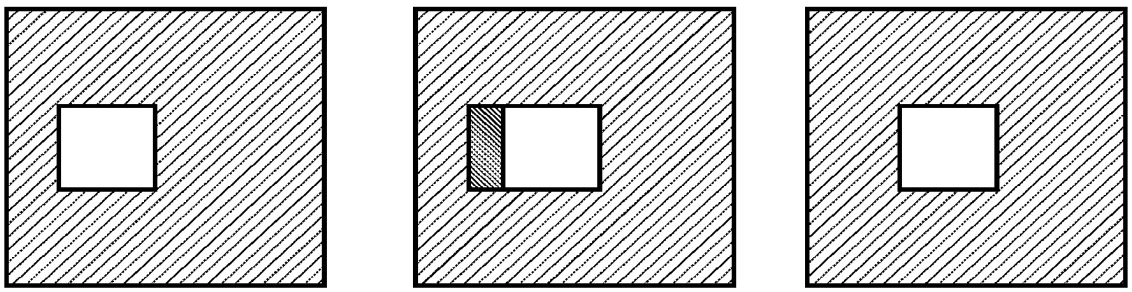
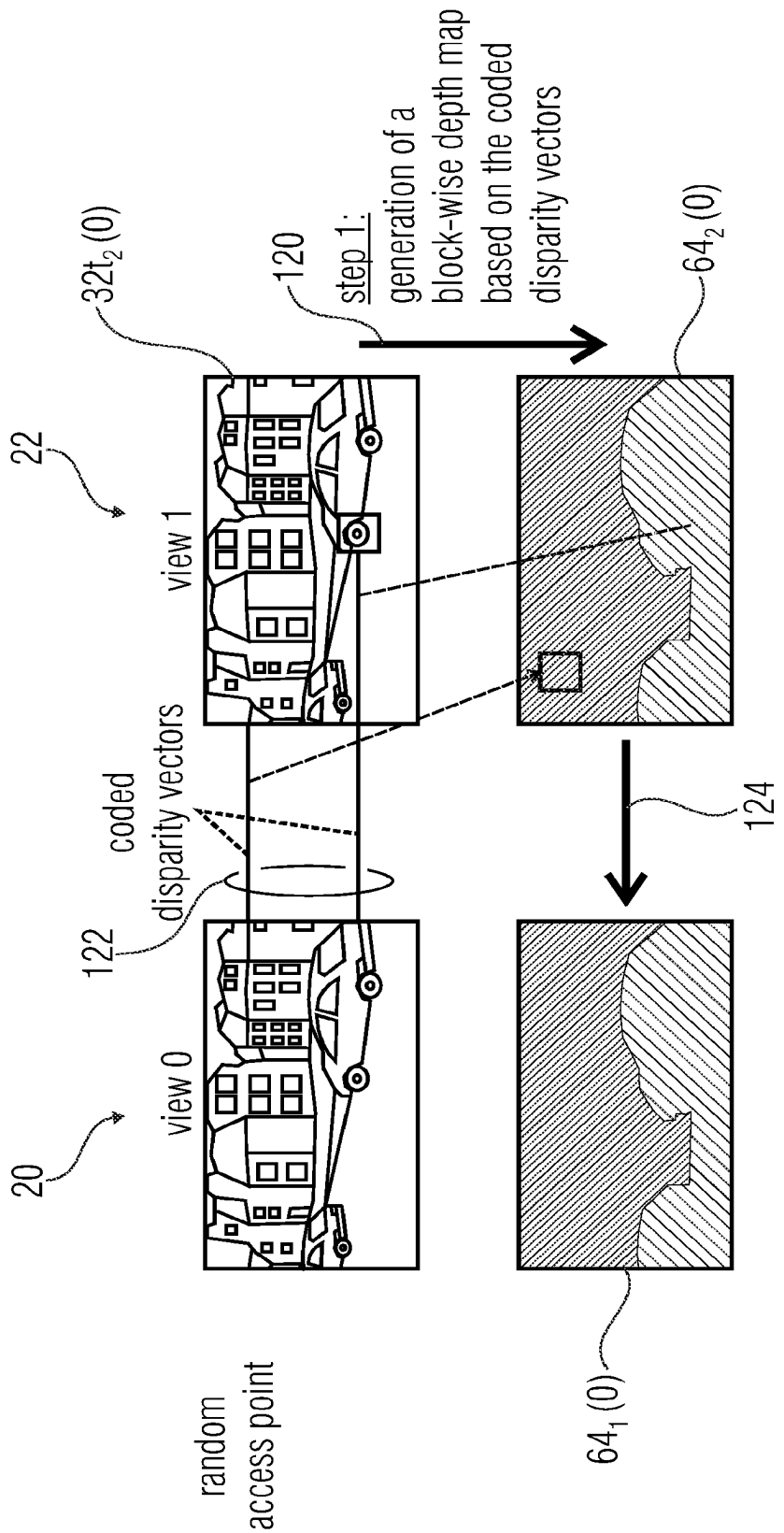


FIG 6



20
view 0
22
view 1
$32t_2$ (0)
120
step 1:
generation of a
block-wise depth map
based on the coded
disparity vectors
64_2 (0)
coded
disparity vectors
122
124
random
access point
64_1 (0)
step2:

FIG 7

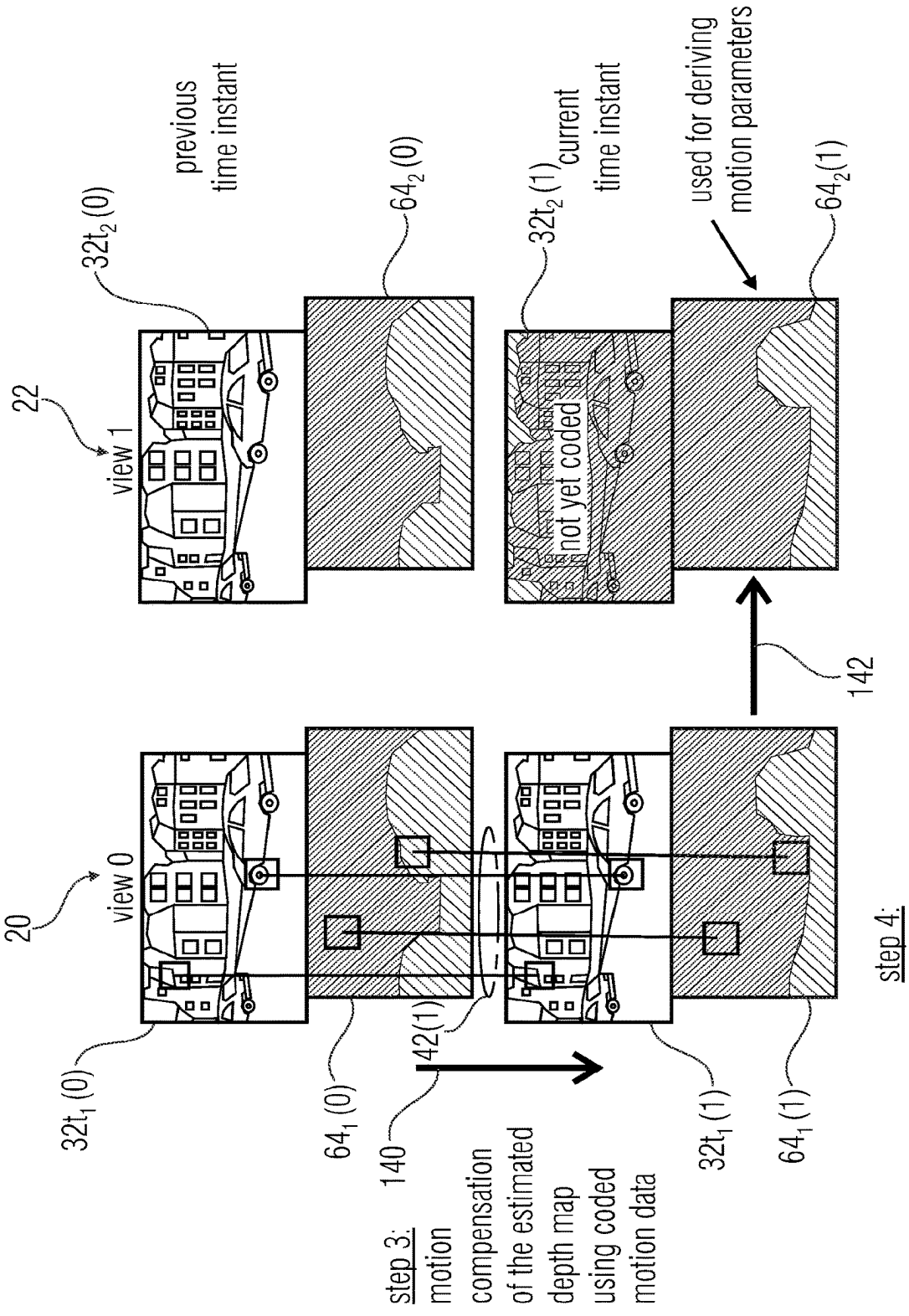

20
view 0
$32t_1(0)$
$64_1(0)$
step 3:
motion
compensation
of the estimated
depth map
using coded
motion data
140
42(1)
$32t_1(1)$
$64_1(1)$
step 4:
142
22
view 1
$32t_2(0)$
previous
time instant
$64_2(0)$
$32t_2(1)$
current
time instant
not yet coded
used for deriving
motion parameters
$64_2(1)$

FIG 8

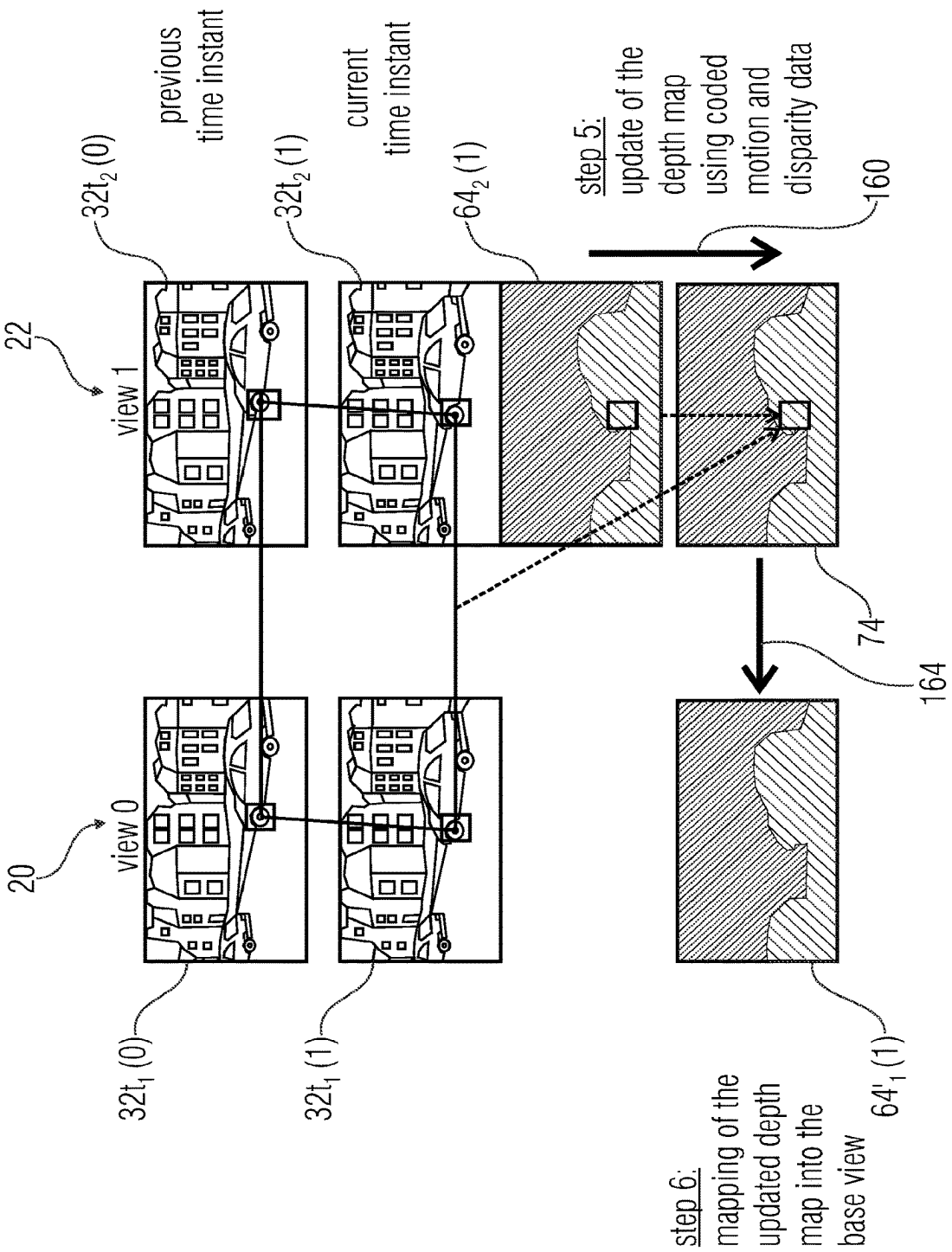

previous time instant
current time instant
step 5: update of the depth map using coded motion and disparity data
step 6: mapping of the updated depth map into the base view
view 1
view 0
22
20
160
74
164
$32t_2(0)$
$32t_2(1)$
$64_2(1)$
$32t_1(0)$
$32t_1(1)$
$64'_1(1)$

FIG 9

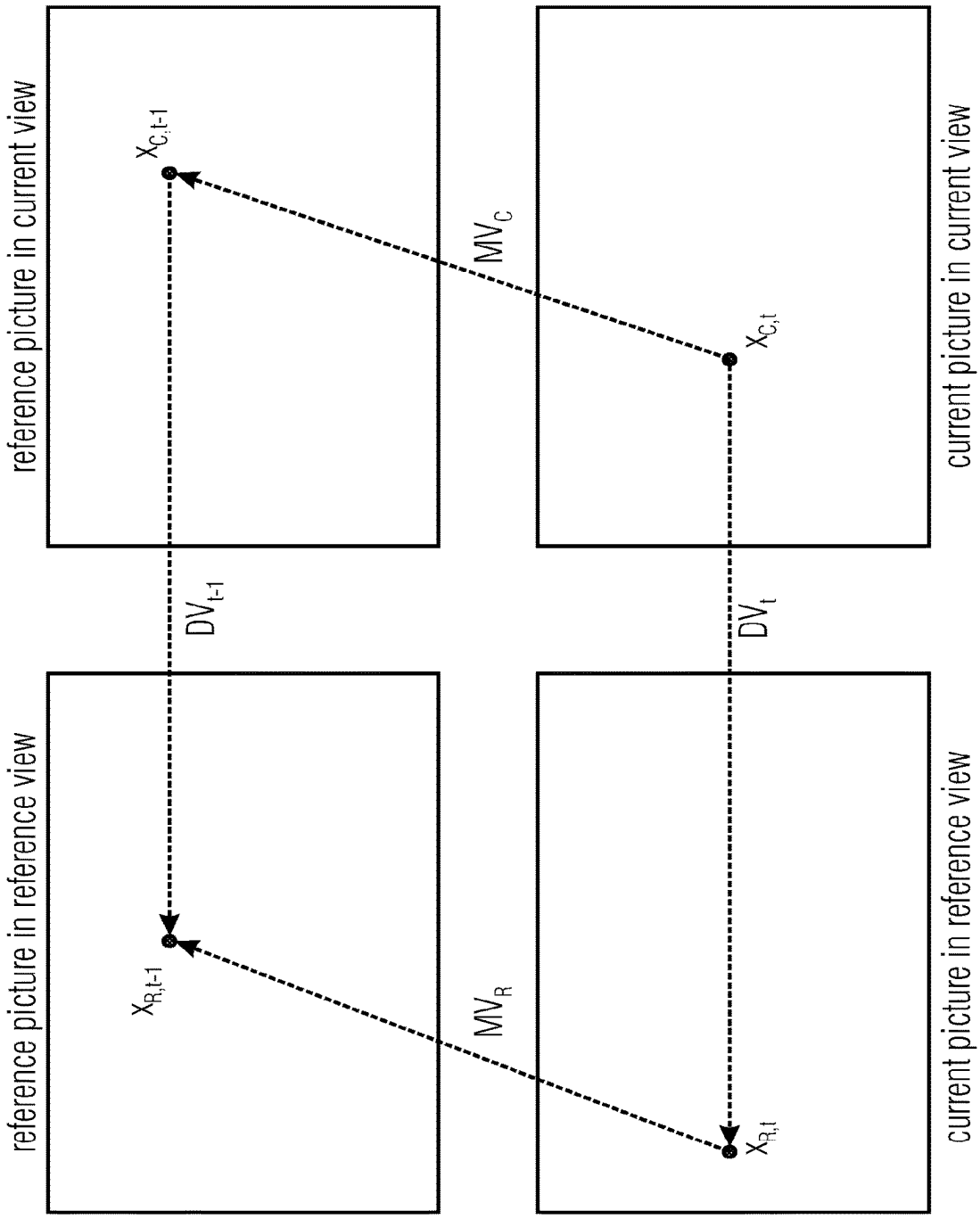

reference picture in current view
current picture in current view
reference picture in reference view
current picture in reference view
$X_{C,t-1}$
MV_C
$X_{C,t}$
DV_{t-1}
DV_t
$X_{R,t-1}$
MV_R
$X_{R,t}$

FIG 10

MULTI-VIEW CODING WITH EFFICIENT RESIDUAL HANDLING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation of U.S. patent application Ser. No. 17/531,478 filed Nov. 19, 2021, which is a continuation of U.S. patent application Ser. No. 16/848,297 filed Apr. 14, 2020 now U.S. Pat. No. 11,184,600, which is a continuation of U.S. patent application Ser. No. 14/277,850 filed May 15, 2014 now U.S. Pat. No. 10,659,754, which is a continuation of International Patent Application PCT/EP2012/072889, filed Nov. 16, 2012, which claims priority from U.S. Patent Application 61/561,452, filed Nov. 18, 2011, all of which are incorporated herein by reference in their entireties.

BACKGROUND OF THE INVENTION

[0002] The present invention is concerned with multi-view coding.

[0003] In multi-view video coding, two or more views of a video scene (which are simultaneously captured by multiple cameras) are coded in a single bitstream. The primary goal of multi-view video coding is to provide the end user with an advanced multimedia experience by offering a 3-d viewing impression. If two views are coded, the two reconstructed video sequences can be displayed on a conventional stereo display (with glasses). However, the necessitated usage of glasses for conventional stereo displays is often annoying for the user. Enabling a high-quality stereo viewing impression without glasses is currently an important topic in research and development. A promising technique for such autostereoscopic displays is based on lenticular lens systems. In principle, an array of cylindrical lenses is mounted on a conventional display in a way that multiple views of a video scene are displayed at the same time. Each view is displayed in a small cone, so that each eye of the user sees a different image; this effect creates the stereo impression without special glasses. However, such autostereoscopic displays necessitate typically 10-30 views of the same video scene (even more views may be necessitated if the technology is improved further). More than 2 views can also be used for providing the user with the possibility to interactively select the viewpoint for a video scene. But the coding of multiple views of a video scene drastically increases the necessitated bit rate in comparison to conventional single-view (2-d) video. Typically, the necessitated bit rate increases approximately linearly with the number of coded views. A concept for reducing the amount of transmitted data for autostereoscopic displays consists of transmitting only a small number of views (perhaps 2-5 views), but additionally transmitting so-called depth maps, which represent the depth (distance of the real world object to the camera) of the image samples for one or more views. Given a small number of coded views with corresponding depth maps, high-quality intermediate views (virtual views that lie between the coded views)—and to some extend also additional views to one or both ends of the camera array—an be created at the receiver side by a suitable rendering techniques.

[0004] For both stereo video coding and general multi-view video coding (with or without depth maps), it is important to exploit the interdependencies between the different views. Since all views represent the same video scene (from a slightly different perspective), there is a large amount of interdependencies between the multiple views. The goal for designing a highly efficient multi-view video coding system is to efficiently exploit these interdependencies. In conventional approaches for multi-view video coding, as for example in the multi-view video coding (MVC) extension of ITU-T Rec. H.264 I ISO/IEC 14496-10, the only technique that exploits view interdependencies is a disparity-compensated prediction of image samples from already coded views, which is conceptually similar to the motion-compensated prediction that is used in conventional 2-d video coding. However, typically only a small subset of image samples is predicted from already coded views, since the temporal motion-compensated prediction is often more effective (the similarity between two temporally successive images is larger than the similarity between neighboring views at the same time instant). In order to further improve the effectiveness of multi-view video coding, it is necessitated to combine the efficient motion-compensated prediction with inter-view prediction techniques. One possibility is to re-use the motion data that are coded in one view for predicting the motion data of other views. Since all views represent the same video scene, the motion in one view is connected to the motion in other views based on the geometry of the real-world scene, which can be represented by depth maps and some camera parameters.

[0005] In state-of-the-art image and video coding, the pictures or particular sets of sample arrays for the pictures are usually decomposed into blocks, which are associated with particular coding parameters. The pictures usually consist of multiple sample arrays (luminance and chrominance). In addition, a picture may also be associated with additional auxiliary samples arrays, which may, for example, specify transparency information or depth maps. Each picture or sample array is usually decomposed into blocks. The blocks (or the corresponding blocks of sample arrays) are predicted by either inter-picture prediction or intra-picture prediction. The blocks can have different sizes and can be either quadratic or rectangular. The partitioning of a picture into blocks can be either fixed by the syntax, or it can be (at least partly) signaled inside the bitstream. Often syntax elements are transmitted that signal the subdivision for blocks of predefined sizes. Such syntax elements may specify whether and how a block is subdivided into smaller blocks and being associated coding parameters, e.g. for the purpose of prediction. For all samples of a block (or the corresponding blocks of sample arrays) the decoding of the associated coding parameters is specified in a certain way. In the example, all samples in a block are predicted using the same set of prediction parameters, such as reference indices (identifying a reference picture in the set of already coded pictures), motion parameters (specifying a measure for the movement of a blocks between a reference picture and the current picture), parameters for specifying the interpolation filter, intra prediction modes, etc. The motion parameters can be represented by displacement vectors with a horizontal and vertical component or by higher order motion parameters such as affine motion parameters consisting of six components. It is also possible that more than one set of particular prediction parameters (such as reference indices and motion parameters) are associated with a single block. In that case, for each set of these particular prediction parameters, a single intermediate prediction signal for the

block (or the corresponding blocks of sample arrays) is generated, and the final prediction signal is built by a combination including superimposing the intermediate prediction signals. The corresponding weighting parameters and potentially also a constant offset (which is added to the weighted sum) can either be fixed for a picture, or a reference picture, or a set of reference pictures, or they can be included in the set of prediction parameters for the corresponding block. The difference between the original blocks (or the corresponding blocks of sample arrays) and their prediction signals, also referred to as the residual signal, is usually transformed and quantized. Often, a two-dimensional transform is applied to the residual signal (or the corresponding sample arrays for the residual block). For transform coding, the blocks (or the corresponding blocks of sample arrays), for which a particular set of prediction parameters has been used, can be further split before applying the transform. The transform blocks can be equal to or smaller than the blocks that are used for prediction. It is also possible that a transform block includes more than one of the blocks that are used for prediction. Different transform blocks can have different sizes and the transform blocks can represent quadratic or rectangular blocks. After transform, the resulting transform coefficients are quantized and so-called transform coefficient levels are obtained. The transform coefficient levels as well as the prediction parameters and, if present, the subdivision information is entropy coded.

[0006] The state-of-the-art in multi-view video coding extends the 2-d video coding techniques in a straightforward way. Conceptually, two or more video sequences, which correspond to the different views, are coded (or decoded) in parallel. Or more specifically, for each access unit (or time instant), the pictures corresponding to the different views are coded in a given view order. An MVC bitstream contains a base view, which can be decoded without any reference to other views. This ensures backwards compatibility with the underlying 2-d video coding standard/scheme. The bitstream is usually constructed in a way that the sub-bitstream corresponding to the base view (and in addition sub-bitstreams corresponding to particular subsets of the coded views) can be extracted in a simple way by discarding some packets of the entire bitstream. In order to exploit dependencies between views, pictures of already coded views of the current access unit can be used for the prediction of blocks of the current view. This prediction is often referred to as disparity-compensated prediction or inter-view prediction. It is basically identical to the motion-compensated prediction in conventional 2-d video coding; the only difference is that the reference picture represents a picture of a different view inside the current access unit (i.e., at the same time instant) and not a picture of the same view at a different time instant. For incorporating inter-view prediction in the design of the underlying 2-d video coding scheme, for each picture, one or more reference picture lists are constructed. For the base view (independently decodable view), only conventional temporal reference pictures are inserted into the reference picture lists. However, for all other views, inter-view reference pictures can be inserted into a reference picture list in addition (or instead of) temporal reference pictures. Which pictures are inserted into a reference picture list determined by the video coding standard/scheme and/or signaled inside the bitstream (e.g., in a parameter set and/or slice header). Whether a temporal or inter-view reference picture is chosen for a particular block of the current view is then signaled by coding (or inferring) a reference picture index. i.e., the inter-view reference pictures are used in exactly the same way as conventional temporal reference pictures; only the construction of the reference picture lists of slightly extended.

[0007] The current state-of-the-art in multi-view video coding is the Multi-view Video Coding (MVC) extension of ITU-T Rec. H.264 1 ISO/IEC JTC 1 [1] [2]. MVC is a straightforward extension of ITU-T Rec. H.264 I ISO/IEC JTC 1 towards multi-view video coding. Beside some extensions of the high level syntax, the only tool that has been added is the disparity-compensated prediction as described above. However, it should be noted that disparity-compensated prediction is typically only used for a small percentage of block. Except for regions that are covered or uncovered due to the motion inside a scene, the temporal motion-compensated prediction typically provides a better prediction signal than the disparity-compensated prediction, in particular if the temporal distance between the current and the reference picture is small. The overall coding efficiency could be improved if the temporal motion-compensated prediction could be combined with suitable inter-view prediction techniques. There is a conceptually similar problem in scalable video coding, where two representations of the same video sequence with different resolutions or fidelities are coded in a single bitstream. For the enhancement layer, there are in principle two possibilities to prediction a block of samples (if we ignore spatial intra prediction), using a temporal motion-compensated prediction from an already coded enhancement layer picture or an inter-layer prediction from the lower layer. In Scalable Video Coding (SVC) extension [3], the conventional temporal motion-compensated prediction has been combined with an inter-layer prediction of motion parameters. For an enhancement layer block, it provides the possibility to reuse the motion data of the co-located base layer block, but apply it to the enhancement layer (i.e., use the enhancement layer reference picture with base layer motion data). In this way, the temporal motion-compensated prediction inside a layer is efficiently combined with an inter-layer prediction of motion data. The general idea behind this technique is that all layers in a scalable bitstream show the same content, and hence also the motion inside each layer is the same. It does not necessarily mean that the best motion parameters for one layer are also the best motion parameters for a following layer due to the following effects: (1) The quantization of the reference pictures modifies the sample values and since different layers are quantized differently, the motion parameters that give the smallest distortion can be different for different layers; (2) Since the layers are coded at different bit rates, a particular set of motion parameters usually corresponds to a different trade-off between rate and distortion. And in rate-distortion optimized coding (which is for example achieved by minimizing of the Lagrangian functional $D+\lambda R$ of the distortion D and the associated rate R), different motion parameters can be optimal in rate-distortion sense for different layers (the operating point given by R as well as the associated distortion or rate can be different). Nonetheless, the (optimal) motion parameters in base and enhancement layer are usually similar. And it is typically very likely that a mode the re-uses the motion parameters of the base layer (and is therefore associated with a small rate R) leads to a smaller overall cost ($D+\lambda R$) than the optimal mode that is independent of the base layer. Or in other words, it is likely

that the distortion increase AD that is associated by choosing the mode with base layer motion data instead of the mode with optimal enhancement motion data is smaller than the cost that is associated with the decrease in rate ($\Delta D<\lambda\Delta R<0$).

[0008] Conceptually, a similar concept as for SVC can also be used in multi-view video coding. The multiple cameras capture the same video scene from different perspective. However, if a real world object moves in the scene, the motion parameters in different captured views are not independent. But in contrast to scalable coding, where the position of an object is the same in all layers (a layer represent just a different resolution or a different quality of the same captured video), the interrelationship of the projected motion is more complicated and depends on several camera parameters as well as on the 3-d relationships in the real-world scene. But if all relevant camera parameters (such as focal length, distance of the cameras, and direction of the optical axis of the cameras) as well as the distance of the projected object points (depth map) are given, the motion inside a particular view can be derived based on the motion of another view. In general, for coding a video sequence or view, we don't need to know the exact motion of the object points; instead simple parameters such as motion vectors for blocks of samples are sufficient. In this spirit, also the relationship of the motion parameters between different views can be simplified to some extent

SUMMARY

[0009] According to an embodiment, an apparatus for reconstructing a multi-view signal coded into a multi-view data stream may have: a reference-view reconstructor configured to predictively reconstruct a current picture of a reference view of the multi-view signal; a dependent-view reconstructor configured to reconstruct the current picture of the dependent view of the multi-view signal using block-based predictive coding, wherein the dependent-view reconstructor is configured to, in reconstructing the current picture of the dependent view, predict a residual signal of the current picture of the dependent view from a reference residual signal of the current picture of the reference view using block-granular disparity-compensated prediction.

[0010] According to another embodiment, an apparatus for encoding a multi-view signal into a multi-view data stream may have: a reference-view encoder configured to predictively encode a current picture of a reference view of the multi-view signal; a dependent-view encoder configured to encode the current picture of the dependent view of the multi-view signal using block-based predictive coding, wherein the dependent-view encoder is configured to, in encoding the current picture of the dependent view, predict a residual signal of the current picture of the dependent view from a reference residual signal of the current picture of the reference view using block-granular disparity-compensated prediction.

[0011] According to another embodiment, a method for reconstructing a multi-view signal coded into a multi-view data stream may have the steps of: predictively reconstructing a current picture of a reference view of the multi-view signal; reconstructing the current picture of the dependent view of the multi-view signal using block-based predictive coding, the reconstructing the current picture of the dependent view includes predicting a residual signal of the current picture of the dependent view from a reference residual signal of the current picture of the reference view using block-granular disparity-compensated prediction.

[0012] According to another embodiment, a method for encoding a multi-view signal into a multi-view data stream may have the steps of: predictively encoding a current picture of a reference view of the multi-view signal; encoding the current picture of the dependent view of the multi-view signal using block-based predictive coding, encoding the current picture of the dependent view includes predicting a residual signal of the current picture of the dependent view from a reference residual signal of the current picture of the reference view using block-granular disparity-compensated prediction.

[0013] Another embodiment may have a computer program having a program code for performing, when running on a computer, an inventive method.

[0014] The basic idea underlying the present invention is that a gain in multi-view coding may be achieved if the residual signal involved with coding a dependent view of the multi-view signal is predicted from a reference residual signal of the current picture of the reference view using block-granular disparity-compensated prediction, i.e. using disparity compensated prediction with a disparity defined at, and varying with, block granularity so that each block of the current picture of the dependent view has its own disparity displacement such as its own disparity vector, associated therewith. In other words, it is an idea of the present invention that a remaining similarity between the residual signal involved with predictively coding the reference view may be used in order to predict the residual signal involved with predictively coding the dependent view, provided that the disparity displacement is estimated at a sufficient spatial resolution and/or at a sufficient estimation accuracy. In this regard, the present invention is also based on the inventors having discovered that disparity information is often available in multi-view data streams for coding the dependent view, such as for blocks of the dependent view coded in an interview block coding mode. Predicting the residual signal of the current picture of the dependent view may, however, not only be performed for blocks for which disparity displacement information is already available in form of disparity data for inter-view coded blocks, or in form of explicitly signaled information within the multi-view view data stream. Rather, embodiments of the present invention reveal that there is enough information within a multi-view data stream so as to estimate such disparity displacement at a sufficient accuracy so that this estimate is also available irrespective from the just-mentioned conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Embodiments of the present invention will be detailed subsequently referring to the appended drawings, in which:

[0016] FIG. **1***a* shows a block diagram of an apparatus for reconstructing a multi-view signal in accordance with an embodiment;

[0017] FIG. **1***b* shows a schematic diagram illustrating components of a multi-view signal in accordance with various embodiments;

[0018] FIG. **1***c* shows schematically a functionality of the embodiment of FIG. **1***a* in accordance with a specific variant with regard to the disparity estimator;

[0019] FIG. **1***d* shows schematically an embodiment of FIG. **1***a* in accordance with a further specific variant for the disparity estimator;

[0020] FIG. **2** shows a block diagram of an apparatus for encoding a multi-view signal fitting to the apparatus of FIG. **1** in accordance with an embodiment;

[0021] FIG. **3** shows a block diagram including FIGS. **3**A and **3**B of an apparatus for reconstructing a multi-view signal in accordance with a more detailed implementation of the embodiment of FIG. **1**;

[0022] FIG. **4** shows a block diagram including FIG. **4**A and **4**B of an apparatus for encoding a multi-view signal fitting to the apparatus of FIG. **3**;

[0023] FIG. **5***a* shows a concept of determining a residual block in an already coded view that is used for predicting the residual of a current block in a current view (example with actual data);

[0024] FIG. **5***b* shows a concept of determining a residual block in an already coded view that is used for predicting the residual of a current block in a current view (example with actual data);

[0025] FIG. **6** shows a basic process for mapping a depth map given for one view to another view: (left) given depth map for a view, where the grey area represents a background and white area represents a foreground object; (middle) converted depth map obtained by displacing the samples with the disparity vectors that corresponds to the depth values and keeping the foreground object for locations to which more than one sample is projected, the black area represents on disoccluded area to which no sample has been projected; (right) converted depth map after filling the disoccluded areas by the depth value for the background;

[0026] FIG. **7** shows a generation of depth maps (using disparity vectors) for a random access unit;

[0027] FIG. **8** shows temporal prediction of an estimated depth map using the motion parameters coded in the base view;

[0028] FIG. **9** shows an update of the depth map using actually coded motion and disparity vectors; and

[0029] FIG. **10** shows a general relationship between projected objects points, temporal motion vectors, and disparity vectors in the pictures of different views and time instances.

DETAILED DESCRIPTION OF THE INVENTION

[0030] FIG. **1***a* shows an embodiment for an apparatus **10** for reconstructing a multi-view signal **12** coded into a multi-view data stream **14**. The apparatus **10** comprises an input **16** for the multi-view data stream **14**, and two outputs **18***a* and **18***b* for a reference view signal **20** and a dependent view signal **22**, respectively. Further, apparatus **10** comprises a reference-view reconstructor **24** connected between input **16** and output **18***a*, and a dependent-view reconstructor **26** connected between input **16** and output **18***b*. Optionally, a depth map estimator **28** of apparatus **10** may be connected between reference-view reconstructor **24** and dependent-view reconstructor **26** with a significance and the way of connection being set out in more detail below.

[0031] The apparatus or decoder **10** of FIG. **1** is configured to reconstruct the multi-view signal **12** from the multi-view data stream **14**. In doing so, the apparatus may obey a predetermined coding/decoding order according to which the reference signal **20** is processed prior to dependent view **22**.

[0032] FIG. **1***b* illustrates possible components within multi-view signal **12**. As illustrated in FIG. **1***b*, the multi-view signal **12** may not only represent a spatial sampling of one common scene from different view directions or view points associated with respective views **20** and **22**, but also a temporal sampling of this scene as it is illustrated in FIG. **1***b* exemplarily by showing three consecutive time instants T−1, T and T+1 along a time axis **30**. For each time instant, each view **20** and **22** comprises a picture **32***t*$_1$ and **32***t*$_2$, respectively, with a time instant to which these pictures belong, being indicated in FIG. **1***b* in parenthesis. Each picture **32***t*$_{1,2}$ represents a respective texture map, i.e. a spatial sampling of the color, luminance, intensity or brightness in this scene as seen from the respective view points, respectively.

[0033] It is noted that FIG. **1***b* shows both views **20** and **22** as having their pictures **32***ti*,**2** temporally aligned. However, this is not necessarily the case. The pictures **32***t*$_1$ and **32***t*$_2$ may be interlaced, or the time resolution between view **20** and view **22** may even differ.

[0034] The decoder **10** is configured to process, or reconstruct, the multi-view signal **12** sequentially in time. To be more precise, decoder **10** is configured to reconstruct the pictures **32***t*$_{1,2}$ of the views **20** and **22** of the multi-view signal **12** of a certain time instant, such as T−1, prior to continuing with processing the views **20** and **22** regarding the subsequent time instant T, i.e. prior to reconstructing pictures **32***t*$_{1,2}$ (T). In this regard, it is noted that the temporal coding order among the time instants of the multi-view signal **12** may be equal to the presentation time order of the pictures **32***t*$_{1,2}$ or may differ therefrom.

[0035] As also shown in FIG. **1***b*, the multi-view signal **12** may additionally not only represent a spatial or spatio-temporal sampling of the texture of the common scene from the different view directions or view points associated with the respective views **20** and **22**, but also a spatial or spatio-temporal sampling of this scene with regard to depth. For example, as illustrated in FIG. **1***b*, each picture **32***t*$_{1,2}$ may comprise, or may have associated therewith, a respective depth map **34***dt*$_1$ and **34***dt*$_2$. As known in the art, the additional information sent by these depth maps **34***dt*$_{1,2}$ may be used by an intermediate-view synthesizer downstream to output **18***a* and **18***b*, respectively, in order to synthesize intermediate views between views **20** and **22** from the pictures **32***t*$_{1,2}$. Regarding the afore-mentioned coding order, the decoder **10** may be configured to use a decoding order according to which the texture of the reference view is reconstructed prior to the associated depth, with merely then stepping forward to reconstruct the texture, followed by its depth map, of the dependent view of the same time instant, wherein after the same information is reconstructed for the next time instant and so forth.

[0036] It is noted that FIG. **1** assumes that each picture **32***t*$_{1,2}$ comprises a respective depth map **34***dt*$_{1,2}$, but this does not need to be the case. The temporal resolution of the depth map **34***dt*$_{1,2}$ may differ from the associated sequence of pictures **32***t*$_{1,2}$. Moreover, even the time resolution between views **20** and **22** may differ. Naturally, the same applies to the spatial resolution of the texture and depth maps. Texture map resolution and depth resolution may differ from each other in time and/or spatial dimensions.

[0037] Finally with regard to FIG. **1***b*, it is noted that the term "picture" is used herein in two meanings, namely first, to denote the conglomeration of all spatially sampled information of a respective view for a certain time instant, such as texture and depth map together, and second, merely the texture at the current time instant. The context will reveal which meaning is respectively meant.

[0038] Thus, back to FIG. **1***a*, the mode of operation of decoder **10** shall be explained. As already noted above, decoder **10** is configured to process the multi-view signal **12**, i.e. to reconstruct same, sequentially in time. To be more precise, decoder **10** may be configured to reconstruct the pictures $32t_{1,2}$ and the respective depth maps $34dt_{1,2}$ of a certain time instant, such as T−1, prior to continuing with processing the pictures and depth maps of another time instant T. In particular, the reference-view reconstructor **24** is configured to reconstruct the reference view **20**, while dependent-view reconstructor **26** is configured to reconstruct the dependent view **22**. Reference-view reconstructor **24** reconstructs the reference view **20** from a reference view portion **36** of the multi-view data stream **14**, while dependent-view reconstructor **26** reconstructs the dependent view **22** based on a dependent view portion **38** of the multi-view data stream **14**. In fact, reference-view reconstructor **24** and dependent-view reconstructor **26** may be configured to operate in a similar manner. For example, reference reconstructor **24** and dependent-view reconstructor **26** both use predictive coding in order to reconstruct the respective signal **20** and **22**, respectively. The dependent-view reconstructor is configured to reconstruct the dependent view **22** of the multi-view signal **12** using block-based predictive coding, and the reference-view reconstructor may likewise use block-based predictive coding in order to reconstruct the reference view **20** of the multi-view signal **12**. Both may, for example, be configured as a hybrid video decoder, respectively. The reference-view reconstructor **24** reconstructs, for example, the picture or texture map $32t_1$ of a current time instant T by assigning a respective one of available block coding modes to the blocks **40** into which this picture is subdivided. The subdivision of the picture $32t_1$ into blocks may be predefined by default, or may be signaled within the multi-view data stream **14**. The subdivision may subdivide picture $32t_1$ in a regular manner into blocks of the same size or blocks of different size. For example, the sub-division may first subdivide the picture regularly into rows and columns of tree-root blocks which, in turn, are sub-divided using multi-tree subdivisioning with the information concerning the latter being, for example, signaled for each tree-root block in the data stream **14**. In other words, a multi-tree subdivisioning may be possible so that the block size of the blocks **40** may be locally adapted to the picture content.

[0039] The coding modes available may comprise one or more intra prediction modes according to which reference-view reconstructor **24** fills the respective block **40** by prediction from already reconstructed samples of already reconstructed blocks preceding the current block in a decoding order defined among the blocks of picture **32t1**, and/or one or more inter prediction block coding modes according to which reference-view reconstructor **24** reconstructs the respective block by motion compensated prediction using motion data such as motion vectors, reference picture indices and the like. For example, for illustration purposes two blocks are exemplarily shown to be reconstructed by inter prediction. The motion data **42** for these inter-predicted blocks may comprise motion vectors used by reference-view reconstructor **24** to copy respective portions of a reconstructed version of a reference picture $32t_1$ indexed by a reference index also comprised by the motion data **42**. The motion data **42** is comprised by the reference view portion **36** of multi-view data stream **14**.

[0040] Reference-view reconstructor **24** may, however, also be responsible for reconstructing the depth map $34d_1$, if present, of the current picture $32t_1$ of the current time instance T of the reference view **20** from a reference view depth map portion of portion **36**. As illustrated in FIG. **1***a*, reference-view reconstructor **24** may also use a block-wise processing in order to reconstruct the depth map $34d_1$. The subdivision of depth map $34d_1$ may be spatially adopted from the subdivision of the corresponding picture $32t_1$, or subdivision information may be contained in multi-view data stream **14** with regard to depth map $34d_1$. The coding modes which reference-view reconstructor **24** supports for the blocks **44** of depth map **34***th* may or may not comprise the coding modes available for blocks **40** of picture $32t_1$. Additionally, however, other coding modes may be available as well. For example, some blocks of depth map $34d_1$ may be predicted from already reconstructed portions **40** of picture $32t_1$ of the same time instant. It should be noted that even the coding modes assigned to blocks **44** may be adopted by reference-view reconstructor **24** from the coding modes of co-located blocks **40** of picture $32t_1$. Otherwise, the coding modes for blocks **44** and **40** are conveyed within the multi-view data stream **14**. For illustration purposes, two blocks of blocks **44** of depth map $34d_1$ are exemplarily shown to be inter predicted using motion data **46**, such as by copying from corresponding portions-i.e. portions pointed to by a motion vector of the motion data from a position co-located to the respective block-of a referenced, already reconstructed depth map $34d_1$ indexed, for example, by a reference index which may also be comprised by the motion data **46** optionally.

[0041] Similarly to the coding modes, motion data **46** may be adopted for motion data **42**, or at least predicted therefrom. Together, motion data **42** and motion data **46** represent motion data **48** of the current picture or time instant T of view **20**.

[0042] The dependent-view reconstructor **26** may operate quite the same as reference-view reconstructor **24** with dependent-view reconstructor **26**, however, being configured to reconstruct the dependent view **22** from the dependent view portion **38**. Accordingly, in reconstructing a current picture $32t_2$ of current time instant T, dependent-view reconstructor **26** may also use a block-wise processing using a subdivision into blocks **50** which may be fixed or signaled within multi-view data stream **14**. Alternatively, depth map based inter-view prediction of the subdivision into blocks **50** as outlined in more detail below may be used by dependent-view reconstructor **26** so as to derive the subdivision into blocks **50** for view **22** from the subdivision into blocks **40** and/or blocks **44** of view **20**. Dependent-view reconstructor **26** may also use such a subdivisioning into blocks **52** for depth map $34d_2$ of view **22**. As far as the coding modes are concerned, dependent-view reconstructor **26** may support coding modes as they have been described with respect to the reference-view reconstructor **24**. Accordingly, illustratively, two blocks **50** and two blocks **52** are exemplarily shown to be subject to inter prediction using motion data **54** and **56**, respectively, so as to be appropriately

copied from respective portions of a reconstructed version of previously reconstructed pictures $32t_2$ and the respective depth map $34d_2$, respectively. Together, this motion data **54** and **56** represents the motion data for the current picture or current time instance of view **22**. In addition to these coding modes, however, dependent-view reconstructor **26** has the ability to support one or more inter-view prediction modes for using disparity-compensated prediction in order to copy respective blocks from portions of view **20** of the same time instant, which are spatially displaced from a co-located position by an amount and direction defined by associated disparity data. In FIG. **1**, one disparity predicted block in picture $32t_2$ and the depth map $34d_2$ are exemplarily shown along with the corresponding disparity data **60** and **62**, respectively. Disparity data may, for example, comprise a disparity vector or at least a disparity component along the view offset direction between views **20** and **22**, and optionally a view index indicating the reference view from which the respective block of the dependent view **22** depends, which index may be favorable in case of the coexistence of more than two views as exemplarily shown in FIG. **1**. Together, disparity data **60** and **62** form the disparity data for the current picture or current time instance T of view **22**.

[0043] That is, reference-view reconstructor **24** and dependent-view reconstructor **26** may operate in a manner so as to reduce the redundancies between a picture and its depth map, along the time axis **30** and in inter-view direction, between views **20** and **22**, as far as possible. This is also true, for example, for the prediction of the side information such as the motion data and disparity data as well as the coding modes and the subdivision information mentioned above. All of this information shows redundancies among each other in time direction, between the views and between a picture and its depth map.

[0044] Until now, the description of FIG. **1***a* focused on a possible base implementation for decoder **10** and reference-view reconstructor **24** and dependent-view reconstructor **26**, respectively. However, the base implementation may also be different. The above description is merely to be regarded as one possible implementation, but other coding concepts underlying reference-view reconstructor **24** and other predictive block-based coding concepts for dependent-view reconstructor **26** would also be feasible.

[0045] Proceeding with a most-interesting feature of the decoder of FIG. **1***a*, due to the predictive coding nature of the operation of reference-view reconstructor **24**, reference-view reconstructor **24** internally reconstructs a current picture of reference view **20** of the multi-view signal **12** via a prediction signal predicted from previously reconstructed portions of the multi-view signal **12**, such as a previously reconstructed portion of the reference view **20**, and a residual signal which reference-view reconstructor **24** derives from portion **36** of multi-view data stream **14**. In particular, owing to the predictive coding nature, reference-view reconstructor **24** refines the prediction signal with the residual signal such as by adding, although other possibilities would also exist. This residual signal internally obtained within reference-view reconstructor **24** may serve as a reference residual signal **63** for dependent-view reconstructor **26**. Accordingly, FIG. **1***a* shows reference-view reconstructor **24** as being connected to a reference input of dependent-view reconstructor **26**. The dependent-view reconstructor **26** is configured to, in reconstructing the current picture of the dependent view **22**, predict a residual signal for block-based predictively coding of the current picture of the dependent view **22** from this reference residual signal **63** using block-granular disparity-compensated prediction. That is, in case of the dependent-view reconstructor **26** being implemented as a hybrid video decoder as outlined above, dependent-view reconstructor **26** may support a coding option for blocks **50**, or **50** and **52**, according to which the residual signal for refining the prediction signal as obtained via the aforementioned block coding modes, such as intra, inter and/or inter-view block coding mode, is refined by a residual signal which, in turn, is predicted from the reference residual signal **63** by use of block-individually defined disparity displacement such a displacement vectors. That is, dependent-view reconstructor **26** may predict the residual signal for a block **50** or **52** of the dependent view **22** via copying a respective portion of the reference residual signal **63** of the current picture of the reference view **20**, displaced from a location corresponding to this block of the current picture of the dependent view **22** according to the disparity displacement such as the afore-mentioned disparity vector. There are different possibilities for as to how the disparity displacement for the respective block may be obtained, with these possibilities outlined in more detail below. In any case, due to the prediction of the residual signal for the current picture of the dependent view **22**, dependent-view reconstructor **26** may not even have to refine the predicted residual signal of the current picture of the dependent view based on an second order prediction signal explicitly signaled within the multi-view data stream **14** and portion **38** thereof, respectively.

[0046] Thus, in the following description, different possibilities are described for as to how to obtain the disparity displacement for the currently reconstructed block of the current picture of the dependent view **22**. A further discussion will reveal different possibilities for realizing the block-based disparity-compensated prediction using the derived disparity displacement. However, before turning to the discussion of these possible implementation details, the above description of a possible base implementation is finalized with regard to further inter-view redundancy removal features which could be implemented in the decoder of FIG. **10** in case of an implementation thereof in the form of an hybrid video decoder-inter-layer redundancy removal features also using the block-based disparity compensation using the derived disparity displacement for the blocks.

[0047] For example, in order to more efficiently exploit the redundancy between views **20** and **22**, the dependent-view reconstructor **26** may be configured to-with the preliminary assumption that the dependent-view reconstructor **26** has the block-individual disparity displacement at hand—predict the motion data **54** and/or **56** of inter-predicted blocks of the current picture (including its depth map $34d_2$, if present) of the dependent view **22** based on the disparity displacement for these inter-predicted blocks within view **22**. Then, this predicted motion data is used in motion-compensated predicting these blocks. For example, the dependent-view reconstructor **24** may be configured to, in predicting the motion data **54** and/or **56** for a current block **50**/**52**, use the respective disparity displacement for the current block **50**/**52** to locate one or more corresponding positions at the current time instant of the reference view **20** and use the motion data for the one or more blocks of the reference view **20** at the located positions to serve as a predictor for the motion data **54**/**56** of the current block of the current picture of the

dependent view **22**. Naturally, refinement data in order to signal a prediction residual for the motion data **54**/**56** may be comprised by the dependent view portion **38**, i.e. motion residual data, and used by dependent-view reconstructor **26** to refine the motion data **54**/**56**. Even the combination is possible: blocks **50**/**52** of the inter block coding mode, the motion data of which has been predicted from motion data **42**/**46** of blocks **40**/**44** located at positions determined by the respective disparity displacement for the blocks **50**/**52**, may be refined using a residual signal which, in turn, is likewise predicted by copying a respective disparity-displaced portion from the reference residual signal.

[0048] The following description is structured as follows. First, an embodiment for an encoder fitting to the decoder of FIG. **1***a* is described with respect to FIG. **2**. Then, a more detailed implementation possibility for the decoder and encoder of FIGS. **1***a* and **2** is described with respect to FIGS. **3** and **4**. Thereinafter, different possibilities for obtaining the disparity displacement for the individual blocks of the current picture of the dependent view are discussed. Later, specific implementation details concerning the disparity-compensated residual prediction are discussed. Then, specific possibilities for the mode of operation for the disparity estimator **28** are discussed in accordance with two specific ways of providing the disparity displacement data. Finally, further possible advantageous implementations details are described.

[0049] FIG. **2** shows an apparatus for encoding the multi-view signal **12** into the multi-view data stream **14** and comprises, to this end, a reference view encoder **80** and a dependent-view encoder **82**. Optionally, encoder **90** of FIG. **2** may comprise a disparity estimator **84** connected between reference-view encoder **80** and dependent-view encoder **82**. Analogously to decoder **10** of FIG. **1***a*, reference view encoder **80** is configured to predictively encode the reference view **20** of the multi-view signal **12** while dependent-view encoder **82** is configured to encode the dependent view **22** of the multi-view signal **12** using block-based predictive coding. The dependent view encoder **82** is configured to, in encoding the current picture of the dependent view **22**, predict a residual signal of the current picture of the dependent view **22** from a reference residual signal **63** of the current picture of the reference view **20** using block-granular disparity-compensated prediction. As is known in the art, encoder **90** of FIG. **2**, although acting very similar to the decoder of FIG. **1***a* as far as the finally chosen and finally coded prediction parameters and residual signals signaled within the multi-view data stream **14** are concerned, differs from the decoder in that the encoder may select the prediction parameters such as coding modes, the prediction parameters associated with the chosen coding modes, the accuracy of coding the residual signal and so forth, out of a magnitude of different possibilities and combinations by optimizing some cost function depending on, for example, compression rate and/or compression distortion.

[0050] As mentioned above, FIG. **3** shows a possible implementation of the decoder of FIG. **1***a* in more detail. According to FIG. **3**, the reference-view reconstructor **24** and the dependent-view reconstructor **26** are structured very similarly, so that the following description of FIG. **3** starts with a description of the internal structure of reference-view reconstructor **24** and then proceeds with the description of dependent-view reconstructor **26**.

[0051] The reference-view reconstructor **24** comprises an input **300** for receiving the reference-view portion **36**, and an output **302** for outputting reference signal **20**. A further output **304** is provided for outputting the reference residual signal **63**. Internally, reference-view reconstructor **24** comprises a data stream extractor **306**, a main predictor **308**, a residual predictor **310**, and an inverse transformer **312**. The data stream extractor **306** is configured to extract prediction parameters **314** and residual data **316** from the reference view portion **36**. The extraction may be based on lossless entropy decoding such as VLC or arithmetic decoding. A prediction parameter output at which the prediction parameters **314** are output, is connected to a parameter input of main predictor **308** and, optionally, with a parameter input of residual predictor **310**. A residual output of data stream extractor **306** at which the residual data **316** is output, is connected to an input of inverse transformer **312**. Further, reference-view reconstructor **24** comprises a first combiner—here exemplarily depicted and embodied as an adder—**318** having a first input connected to an output of main predictor **308**, and an output connected to the input of main predictor **308**. Likewise, a second combiner-here exemplarily also embodied and depicted as an adder—**320**, is provided, which has its first input connected to an output of residual predictor **310**. An output of combiner **320** is connected to the second input of combiner **318**, and the second input of combiner **320**, in turn, is connected to an output of inverse transformer **312** so that, altogether, data stream extractor **306**, inverse transformer **312** and combiners **320** and **318** are serially connected—in the order of their mentioning—between input **300** and output **302**. As shown in FIG. **3**, the input of the residual predictor **310** may be connected to its output or to the output of adder **320**. Different options also exist for the connection to reference residual signal output **304**. The output of adder **320**, or the output of residual predictor **310** may be connected to output **304**.

[0052] The functionality of the reference-view reconstructor **24** of FIG. **3** is as follows. The data stream extractor **306** extracts residual data **316** and prediction parameters **314** from the reference-view portion **36** of multi-view data stream **14**. As already outlined with respect to FIG. **1***a*, the reference-view reconstructor **24** operates on a block basis so that the prediction parameters **314**, for example, assign a respective block coding mode to each block of the reference view **20**. For texture blocks **40** (see FIG. **1***b*) an intra prediction mode and an inter prediction mode may be available, with this possibility illustrated in FIG. **3** by showing the main predictor **308** as comprising an intra predictor **308***a* and an inter predictor **308***b*. The prediction parameters **314** may convey prediction parameters specific for the respective block coding mode for the respective blocks **40**. For example, the intra prediction mode, which intra predictor **308***a* is responsible for, may be controlled via an intra prediction direction along which the current block is filled based on previously reconstructed samples of neighboring, already reconstructed blocks of the current picture. The inter predictor **308***b* is responsible for the inter prediction block coding mode and controlled via motion data conveyed by the prediction parameters **314** so as to copy respective portions of previously reconstructed pictures of the reference view signal **20** with the location of the portions relative to the location of the inter-predicted block, and the reference picture being indicated by the motion data. Gen-

erally, intra predictor **308***a* and inter predictor **308***b* may also be available, and may function similarly, with respect to depth blocks **44** if depth maps are transmitted within the reference view **20**. However, additional predictors not shown in FIG. **3** may be available or predicting the content of the depth map within the current block **44** using already reconstructed portions of the current texture map of view **20**. Altogether, the main predictor **308** provides at its output a prediction signal **322**, some blocks of which have been obtained by intra prediction while others have been obtained by inter prediction. Combining this prediction signal **322** at combiner **318** with a residual signal **324** reveals the reconstructed signal, namely the reconstructed reference view **20**.

[0053] Instead of explicitly transmitting this residual signal **324** in full by way of the residual data **316** for all blocks **40**/**44**, the reference-view reconstructor **24** may, optionally, have additionally the residual predictor **310**. It should be immediately noted that the residual predictor **310** forms merely an optional feature of FIG. **3** and may, alternatively, be left away, with the output of inverse transformer **312** being in that case directly connected to the second input of combiner **318** so as to provide the residual signal **324** directly. However, if the residual predictor **310** is present, same may be configured to predict the residual signal **324** temporally by motion compensated prediction so as to obtain a residual prediction signal **326** which, when combined with the second order residual signal as output by inverse transformer **312**, namely **328**, then forms the residual signal **324**.

[0054] The intra predictor **310**a of residual predictor **310** may be configured to use, as a reference, either the reconstructed residual signal **324** of previous (previously reconstructed) pictures, or the residual prediction signal **326** of such previous pictures. That is, intra predictor **310**a may copy a portion out of this reference, located according to respective residual prediction motion data signaled within the prediction parameters **314** for those blocks for which the residual prediction that residual predictor **310** is responsible for, is activated.

[0055] The inverse transformer **312** uses the residual data **316** to form the second order residual signal **328** which is, for blocks for which the residual prediction is turned off, equal to the residual signal **324**. The inverse transformer **312** may perform a block-wise transform such as IDCT or the like, in order to obtain signal **328** from respective transform coefficient levels within residual data **316**. The transform blocks within which inverse transformer **312** performs the individual transformations may coincide with the blocks for which the block coding modes are signaled within parameters **314** or may form a subdivision thereof, with a subdivision possibly signaled within residual data **316**. Alternatively, transform blocks may cross block boundaries of blocks **40**/**44**.

[0056] Beyond the just provided description of FIG. **3**, the other specific details mentioned above with respect to FIG. **1***a* are also valid for FIG. **3**. For example, prediction parameters for a current block may be predicted from prediction parameters of previously reconstructed blocks of the same picture or a previous picture of the reference view **22**. This also applies to the coding mode of the current block. Further, all of the above mentioned possibilities with regard to the subdivision of the current picture into blocks **40**/**44** are also valid for FIG. **3**.

[0057] As already mentioned at the beginning of the description of FIG. **3**, the internal structure of the dependent-view reconstructor **26** largely coincides with that of reference-view reconstructor **24**, and accordingly the same reference signs are used for the internal elements of dependent-view reconstructor **26** as far as these elements likewise occurring within the reference-view reconstructor **24**, are concerned. The only difference is an apostrophe used for elements within the dependent-view reconstructor **26**. Focusing on the difference in the internal structure of reconstructors **24** and **26**, residual predictor **310'** is no longer an optional feature. Rather, the residual predictor **310'** renders, at least for some blocks **50**/**52** of the dependent view **22**, an interview residual prediction mode available for which an inter-view predictor **330** of residual predictor **310'** assumes responsibility. An inter residual predictor **310**b' may optionally also by present so as to perform a alternative way of predicting the residual, namely vie respective residual prediction motion data as described above with respect to module **310***b*. The inter-view residual predictor **330** is connected between a reference residual signal input **332** of dependent-view reconstructor **26** which, in turn, is connected to the reference residual signal output **304** of reference-view reconstructor **24** so as to receive the reference residual signal **63**, and, via the output of residual predictor **310'**, to the first input of combiner **320'**. A further difference to reference-view reconstructor **24**, is related to the additional presence of an interview prediction mode within main predictor **308'**, which an inter-view predictor **308***c'* is responsible for. The inter-view predictor **308***c'* copies respective portions of the reconstructed current picture of the reference signal **20** of the same time instant, located at a position determined by disparity data associated with the respective disparity-compensated block **50**/**52**. A respective connection connecting inter-view predictor **308***c'* with the output of combiner **318** of reference-view reconstructor **24** is not shown in FIG. **3** for the sake of focusing the present description to the residual prediction performed by inter-view predictor **330**.

[0058] In any case, the prediction signal **322'** of the dependent-view reconstructor **26** is, in accordance with the specific example of FIG. **3**, composed of blocks being obtained by intra prediction, blocks obtained by inter prediction and blocks obtained by inter-view prediction. For some of these blocks for which the residual prediction option is turned on by prediction parameters **314'**, inter-view predictor **330** predicts the residual signal **324'** by copying a respective portion out of the residual signal **324** for the current picture of the reference view, or the residual prediction signal **326** for the current picture of the reference view **20**, i.e. the reference residual signal **63**. The position of the respective portion is determined by inter-view predictor **330** by use of a disparity displacement specific to this block. Different possibilities exist as to how inter-view predictor **330** determines the disparity displacement for the current block, with these different possibilities outlined in more detail below.

[0059] Before beginning to describe the different possibilities for obtaining the disparity displacement underlying the block-based disparity compensated residual prediction for the embodiment of FIG. **1***a* and the implementation of FIG. **3**, it shall be noted that not only the residual predictor **310** of the reference-view reconstructor **24** is optional, but also the inverse transformers **312** and **312'**, which may be

left away with the second order residual signal **328** being then signaled in the spatial domain within residual data **316** rather than in the transform domain as it was described above. Moreover, the inter predictor **310***b*' is optional as already noted above.

[0060] Further, for the sake of completeness, FIG. **4** shows an embodiment for an encoder fitting to the decoder of FIG. **3**. Many of the elements within the encoder of FIG. **4** are equal to those, or correspond to those, indicated in FIG. **3**, and accordingly, all of these elements are not described again. Rather, the elements differing from the decoder structure of FIG. **3** are described, wherein it is additionally pointed out that, naturally, the encoder of FIG. **4** first selects all the prediction parameters and the residual data finally transmitted within the data stream in accordance with some optimization routine as already outlined above.

[0061] In particular, the reference-view encoder **80** comprises an input **400** at which reference view signal **20** enters, and an output **402** at which the reference view portion **36** of multi-view data stream **14** is output. Internally, reference-view encoder **80** comprises two subtracters **404** and **406**, a transformer **408** and a data stream inserter **410** connected in series to each other between input **400** and output **402**. The inverting input of subtracter **404** is connected to the output of main predictor **308** so as to receive the prediction signal **322**. Subtracter **406** is arranged downstream to subtracter **404** so as to have its non-inverting input connected to the output of subtracter **404**. Further, the inverting input of subtracter **406** is connected to the output of residual predictor **310**. As a further difference to the structure shown in FIG. **3**, the main predictor **308** and the residual predictor **310** have a prediction parameter output rather than a prediction parameter input as their functionality also encompasses the finding of the optimal set of prediction parameters and sending these prediction parameters **314** finally selected to a respective prediction parameter input of data stream inserter **410**. Likewise, the transformer **408** outputs the residual data **316** to a residual input of data stream inserter **410**. The remaining elements of reference-view encoder **80** correspond to those indicated above with respect to FIG. **3**. Likewise, the dependent-view encoder **82** differs from the construction of the dependent-view reconstructor **26** in the way indicated in FIG. **4**. That is, the differences correspond to those already described with respect to the reference-view encoder **80** compared to the reference-view reconstructor **24**. For the sake of completeness, it is noted that the transformers **408** and **408'**, which perform a spectral decomposition such as an DCT, may be left away in case of the inverse transformers **312** and **312'** being left away as well.

[0062] Thus, the functionality of the encoders **80** and **82** largely coincides with the functionality described above with respect to the decoder of FIG. **3**. The subtracters **404** and **406** operate on the original versions of reference and dependent view **20** and **22** so as to obtain the actual first order residual signal **412** and the actual second order residual signal **414** (which may represent the first order residual signal in case of the residual prediction mode being switched off), wherein the transformer **408** lossy encodes the actual second order signal **414** so as to derive the residual data **316**, i.e. the residual data in the transform domain. The data stream inserter **410** may, corresponding to the data stream extractor **306**, perform a lossless entropy coding such as VLC or arithmetic coding so as to insert the residual data **316** and the prediction parameters **314** into the reference-view portion **36** and dependent-view portion **38**, respectively.

[0063] Now, after having described the embodiments of FIG. **1***a* and **2**, and the corresponding possible detailed implementations with respect to FIGS. **3** and **4**, in the following, possible variants in order to obtain the disparity displacement underlying the block-based disparity compensated residual prediction are described with respect to these figures.

[0064] For example, in accordance with a first variant, the disparity displacement underlying the block-based disparity compensated residual prediction is obtained from an explicitly signaled depth-map **34***d*$_1$ (T) of the current picture **32***t*$_1$ of the reference view **20**. In particular, in accordance with this variant, the reference-view reconstructor **24** is configured to predictively reconstruct the current picture **32***t*$_1$ of the reference view **20** of the multi-view signal **12**, including the depth map **34***d*$_1$ of the current picture of the reference view **20**, so as to obtain a reconstructed version of the depth map **34***d*$_1$ (T). Looking at FIG. **3**, this depth map **34***d*$_1$ (T) may be coupled to disparity estimator **28** which, in accordance with this variant, has, to this end, a reference depth map input connected to the output **302** of the reference-view reconstructor **24**, while an output thereof is connected to a depth map estimate input of inter-view predictor **330**. In accordance with this variant, the disparity estimator **28** is configured to estimate the disparity displacement for a current block **50**/**52** of the current time instant of the dependent view **22** from the reconstructed version of the depth map **34***d*$_1$ (T) of the current time instant T of the reference view **20**, and the dependent-view reconstructor **26** is configured to predict the residual signal **324** of the current block **50**/**52** of the current time instant of the dependent view **22** by copying a portion of the reference residual signal **63**, displaced from a location of the current block **50**/**52** of the current time instant of the dependent view **22** according to the disparity displacement thus estimated.

[0065] For example, and as illustrated in FIG. **1***c*, the disparity estimator may warp **66** a reconstructed version of the depth/disparity map **34***d*$_1$ (T) of the current time instant T of the reference view into the dependent **22** to obtain a depth/disparity map estimate **64** for the current time instant T of the dependent view **22** and obtain the disparity displacement for the current block **50**/**52** from the estimated depth/disparity map **64**. This means the following. Although the description so far suggested that the depth maps indicate the depth of the scene in terms of depth values, a disparity map may be used as well since depth and disparity are related to each other in a known manner. In case of the depth/disparity maps **34***d*$_1$,**2** actually being depth maps, the depth estimator **28** may be configured to, in warping **66** the depth map **34***d*$_1$ of the reference view **20** into the dependent view **22**, derive disparity vectors of the current time instant T of the reference view **20** from the depth map **34***d*$_1$ of the current time instant T of the reference view **20** and apply the derived disparity vectors onto the depth map **34***d*$_1$ of the current time instant of the reference view **20** itself so as to obtain the depth map estimate **64**. The disparity estimator **28** may then obtain the disparity displacement such as the disparity vector, for the current block **50**/**52** subject to inter-view residual prediction, merely by converting the depth value of this estimated depth map **64** at the location of the current block **50**/**52** into a disparity vector, using this

disparity vector in turn in order to copy the thus determined portion from the reference residual signal, as will be outlined in more detail below with respect to FIG. **5**.

[0066] In accordance with the just outlined variant, in order to derive the disparity displacement underlying the disparity compensated residual prediction, the disparity estimator **28** was present in order to provide the disparity displacement for the current block by depth-to-disparity conversion from a co-located portion of the depth map estimate **64**. Favorably, this disparity displacement is available prior to starting the reconstruction of the current time instant of the dependent view **22** in accordance with the coding order outlined above. However, there are also other variants which could be used in order to obtain this disparity displacement.

[0067] In accordance with a second variant, for example, the disparity estimator **28** is configured to estimate the disparity displacement of the current block **50/52** of the current time instant of the dependent view **22**-to be used for inter-view residual prediction-by spatial and/or temporal prediction from a disparity displacement associated with reference blocks within previously reconstructed portions of the dependent view, such as blocks **50/52** of the same time instant or blocks **50/52** of a previous time instant of the dependent view **22**. The disparity displacement associated with such reference blocks may stem from blocks **50/52** coded using the inter-view prediction mode using respective disparity data **60** and **62**, respectively. This disparity data **60/62** may serve as a basis for the estimation of the disparity displacement for the current block **50/52** of the current time instant of the dependent view **22** for which the inter-view residual prediction shall be performed. In accordance with this second variant, the disparity estimator **28** has a disparity data input connected to the prediction parameter output of data stream extractor **306'** and a disparity displacement output connected to a disparity displacement input of inter-view predictor **330**. That is, in that case the, dependent-view reconstructor **26** or, to be more precise, the inter-view predictor **330**, may simply use the estimated disparity displacement for the current block **50/52** in order to locate an adequate portion of the reference residual signal **63** and use this portion for predicting the residual signal **324'** within the current block **50/52**, namely by copying the located portion.

[0068] In accordance with an alternative variant, the disparity displacement for the current block subject to inter-view residual prediction is explicitly signaled within the multi-view data stream **14** and the dependent-view portion **38**, respectively. For example, the dependent-view reconstructor **26** may, in accordance with this variant, be configured to predict the residual signal **324'** within the current block **50/52** by copying a portion of the reference residual signal **63** displaced from a location of the current block **50/52** according to this explicitly signaled disparity displacement. Imagine, for example, the current block **50/52** is, in accordance with the main prediction which the main predictor **308'** is responsible for, associated with the inter-view block coding mode. In that case, this block **50/52** has, anyway, a disparity vector **60**, **62** associated therewith. This vector may be used as the just mentioned explicitly signaled disparity displacement, too.

[0069] In accordance with a further variant, the disparity estimator **28** is configured to estimate a disparity displacement of a current block **50/52** of the current time instant of the dependent view **22** by continuously updating a depth/disparity map of a scene of the multi-view signal **12** using disparity data **60** coded into the multi-view data stream **12** for previously reconstructed pictures $32t_2$ of the dependent view **22** and motion data **42** coded into the multi-view data stream **14** for previously reconstructed pictures as well as the current picture $32t_2$ of the reference view **20** and deriving the estimated disparity displacement of the current block **50/52** of the current time instant of the dependent view **22** from the continuously updated depth/disparity map. At random access points, the depth/disparity map estimate is initialized based on the disparity data of the picture $32t_2$ at the random access point. That is, in accordance with this variant, the multi-view signal **12** may not even comprise depth maps, neither for the reference view **20** nor for the dependent view **22**. Rather, in accordance with this variant, the disparity estimator **28** is configured to virtually provide such a depth/disparity map estimate by a continuous update using the information conveyed by the multi-view data stream in form of the motion data **42** and the disparity data **60**. In accordance with this variant, the disparity estimator **28** has a motion/disparity input connected to the prediction parameter outputs of data stream extractors **306** and **306'**, and a disparity displacement output connected to a disparity displacement input of interview predictor **330**.

[0070] With regard to FIG. **1***d*, the just outlined variant is described in more detail. In particular, in accordance with this variant, the disparity estimator **28** ensures that each picture $32t_{1,2}$ has a depth/disparity map estimate **64** associated therewith, the estimate **64** being consecutively derived from each other in a chain of updates. That is, although the continuous update could pertain to a disparity map estimate as well, it is preliminarily assumed that the estimate concerns depth data. The disparity estimator **28** is configured to continuously update the depth map estimate **64** in a ping pong manner between views **20** and **22** primarily with the aim to provide each picture $32t_2$ of the dependent view **22** with such a depth map estimate **64** in order serve as a basis for the above outlined improved inter-view redundancy reduction including the inter-view disparity compensated block-based residual prediction.

[0071] Primarily, it is assumed that the disparity estimator **28** already has access to such a depth estimate for one or more previous pictures $32t_1$ of the reference view **20** such as time instance T-**1**. A way how disparity estimator **28** could have gained access to this depth map estimate **74** for the previously decoded picture $32t_1$ of the reference view **20** is described further below. It should be noted, however, that such depth map data could be intermittently signaled explicitly within the multi-view data stream **14** for first pictures $32t_1$ of the reference view **20** within so called random access units, i.e. groups of pictures $32t_1$ which are decodable without reference to any previous portions of signal **12**. In order to illustrate this possibility, a dashed line connects disparity estimator **28** with input **16**. In the following description, a possibility is presented where the extra transmission of such starting depth map is not necessitated. Rather, the disparity data within the data stream portion **38** for the first picture $32t_2$ of the dependent view **22** in coding order within the random access unit is exploited to construct the starting depth map of the first picture $32t_1$ of the reference view **20** in coding order within the random access unit.

[0072] In particular, the disparity estimator **28** is configured to generate the depth map **64** of the current picture $32t_2$

of the dependent view **22** by applying the motion data **42** for the current picture $32t_1$ of the reference view **20** at the current time instance T onto the depth map estimate **74** of any previous picture $32t_1$ of the reference view **20** at the time instant T−1, for example. As already noted above, the reference-view reconstructor **24** reconstructs the current picture $32t_1$ of the reference view **20** using motion compensated prediction based on the motion data **42**, which is signaled within the multi-view data stream **14** for the reference view **20**. The disparity estimator **28** has access to this motion data **42** and uses this motion data **42** for one of the mentioned updates of the chain of updates, namely the transition **71** from the depth map estimate **74** of the reference picture $32t_1$ at the previous time instant T−1 to the depth map estimate **64** of the current picture $32t_1$ at the current time instant T. A way how this may be performed will be outlined in more detail below. Preliminarily, it shall be sufficient to note that applying **71** the motion data **42** onto the depth map **74** for the previous time instance T−1 could mean that co-located blocks **72**, i.e. portions within depth map estimate **64** of the current picture $32t_1$ which are co-located to blocks **40** for which this motion data **42** has been signaled in the stream portion **36**, are updated with, i.e. copied from, content of the referenced depth map estimate, i.e. the depth map estimate **74** for the picture $32t_1$ of the previous time instance T−1 at portions within the referenced depth map estimate **74** pointed to by the motion data **42'** equal to motion data **42**. Remaining holes may be filled by interpolation and/or extrapolation exploiting additional information offered by the intra-coded blocks among block **40** of the current picture $32t_1$. As a result, the depth map estimate **64** has been updated (or generated by transitioning from T−1 to T).

[0073] Again, disparity estimator **28** performs this update/transition **71** merely in order to prosecute further the chain of updates described further below so as to serve as a basis for deriving the depth map estimate **64** of the current picture $32t_2$ of the dependent view **22** of the same time instants T. To finalize the derivation, disparity estimator **28** warps the updated depth map estimate **64** of the current picture $32t_1$ of the reference view **20** into the dependent view **22** so as to obtain the depth map estimate **64** of the current picture $32t_2$ of the dependent view **22**. That is, as the motion data **42** is defined merely at a block granularity, the update/transition **71** and the resulting depth map estimate **64** of view **22** as resulting from the warping **78** represent a quite coarse estimation of the depth, but as will be shown below such a coarse estimate is sufficient in order to significantly increase the efficiency in performing the inter-view redundancy reduction.

[0074] Although possible details regarding the warping **76** are also described further below, briefly spoken, the dependent-view reconstructor **26** may be configured to perform the warping **78** by deriving disparity vectors from the depth map estimate **64** of current picture $32t_1$ and applying the derived disparity vectors onto the depth map estimate **64** itself, so as to obtain the warped depth map estimate **64** of the current picture $32t_2$ of the dependent view **22**.

[0075] Thus, as soon as disparity estimator **28** has provided dependent-view reconstructor **26** with the result of the warping **76**, namely the depth map estimate **64** of the current time instant T for view **22**, dependent-view reconstructor **26** is able to use this depth map estimate **64** for performing the above-outlined inter-view redundancy reduction for which possible implementations are set out in more detail below.

[0076] However, disparity estimator **28** continues to update **77** this depth map estimate **64** so as to obtain an updated depth map estimate **74** for the current picture $32t_2$ of the reference view **22** and thereby maintaining the chain of updates leading to the estimate for the next time instance T+1. Accordingly, the dependent-view reconstructor **26** is configured to update **77** the depth map estimate **64** of the current picture $32t_2$ of the dependent view **22** of the current time instance T using the disparity and/or motion data **54** and **60** for the dependent view **22** in a manner similar, at least for the motion data **54**, as described above with respect to the update step **71**. That is, the dependent-view reconstructor **26** uses the disparity/motion data for the picture $32t_2$ for time instance T within stream portion **38** for reconstructing this picture $32t_2$. As far as the disparity data **60** is concerned, disparity estimator **28** may easily convert the disparity vectors contained within the disparity data **54** into depth values and assign, based on these depth values, updated depth values to samples of the updated depth map estimate **79**b of the current picture $32t_2$ of the dependent view **22** which are co-located to the respective disparity-predicted block **50** in picture $32t_2$. The motion data **54** could be used so as to copy content of the depth map estimate **74** of the picture $32t_2$ of a referenced previous time instance T−1 of the dependent view **22**, at portions thereof pointed to by motion data equal to motion data **54**, into portions within the updated depth map estimate **74** of the current picture $32t_2$ which are co-located to blocks **50** for which this motion data **42** has been signaled in the stream portion **36**. Remaining holes may be filled by interpolation and/or extrapolation exploiting additional information offered by the intra-coded blocks among block **40** of the current picture $32t_1$. As a result, the updated depth map estimate **74** of the current picture $32t_2$ has been updated (or generated by transitioning from T−1 to T). A possibility for as to how the depth map estimate **74** of the picture $32t_2$ of a referenced previous time instance T−1 of the dependent view **22** may have been derived at the beginning of an random access unit, is described further below. However, the above mentioned possibly explicitly transmitted depth map for view **20** at the beginning of such random access unit may be warped to view **22** to obtain the depth map estimate **74** of the picture $32t_2$ of a referenced previous time instance T−1 of the dependent view **22**, alternatively.

[0077] In order to reduce blocking artifacts, the updates **71** and **77** could be performed by using weighting functions reducing the influence of the updates of the individual blocks at the block borders.

[0078] That is, on the basis of the depth map estimate **64** as obtained by warping **76**, the dependent-view reconstructor **26** reconstructs the current picture $32t_2$ of dependent view **22** using disparity and/or motion compensated prediction based on the disparity and/or motion data **54** and **60** for the dependent view **22** comprised by the dependent view portion **38** of the multi-view data stream **14**, and in doing so, the dependent-view reconstructor **26** provides the disparity estimator **28** with the disparity and/or motion data **54**, **60**, then used by disparity estimator **28** to perform update **77**.

[0079] After this update **77**, the disparity estimator **28** is able to warp-back **78** the updated depth map estimate **74** of the current picture $32t_2$ of the dependent view **22** into the reference view **20** so as to obtain the updated depth map

estimate **74** of current picture **32**t_1 of the reference view **20** for a time instance T which may then serve as a basis/reference for the transition/update **79** to the next time instance T+**1** and so forth.

[0080] From that time on, disparity estimator **28** merely repeats processes **71**, **76**, **77** and **78** iteratively (wherein step **79** corresponds to step **71**) so as to model the depth map estimate along the time axis **30** so as to continuously support the dependent-view reconstructor **26** with the depth map estimate **64**.

[0081] Further details regarding all these steps **71**, **76**, **77**, **78**, and **79** are described in further detail below. All of these further details shall be individually applicable to the description brought forward with regard to FIG. **1**.

[0082] The disparity estimator **28** may then, for a current block **50**/**52** subject to interview residual prediction, derive the disparity displacement, such as a disparity vector, merely by converting the depth value of this estimated depth map **64**, at the location of the current block **50**/**52**, into such a disparity vector, wherein the inter-view predictor **330**, in turn, uses this disparity vector in turn in order to copy the thus determined portion from the reference residual signal **63**, as will be outlined in more detail below with respect to FIG. **5**.

[0083] Thus, the embodiments described so far including the various variants with respect to the disparity displacement derivation for inter-view residual prediction, and possible modifications further various aspects, enable employing coded residual data **63** of already coded views **20** together with already coded disparity **60**/**62** and motion data **42**/**46** for coding a coded picture T of the current view **22** in multi-view video coding. By employing the already coded residual information **63** signaled via residual data **316** together with coded motion/disparity for predicting the residual **324'** of the current/dependent view **22**, the rate associated with coding the residual for the current view **22** can be significantly be reduced since only the remaining residual **328'** has to be performed anymore, which results in an overall bit rate savings for the coding of multi-view video sequences.

[0084] The embodiments outlined above are applicable to general block-based hybrid coding approaches without assuming any particular block partitioning, such as macro block or sub-macro block structure. The general structure of an existing block-based coding/decoding concept does not need to be modified in order to be inserted into the above outlined way of block-based disparity-compensated residual prediction. Only an additional residual prediction step or inter-view predictor **330** needs to be integrated, so that the above embodiments can be integrated in general block-based hybrid video coding schemes with a reasonable complexity increase.

[0085] The above embodiments further provide the possibility to adaptively decide for each block (or a subset of blocks) **50**/**52** whether a residual prediction **330** is applied or not. The disparity information (called disparity displacement) used for referring to a block/portion of the residual **63** of already coded pictures in the reference view **22** can be derived as explained above, including the variants according to FIG. **1***c* and FIG. **1***d* according to which the derivation is based on coded depth maps (if present) or based on coded disparity vectors **60**. In alternative embodiments, the disparity information/disparity displacement used for inter-view residual prediction can be explicitly coded as a part of the data stream **14**. Further, a correction of the disparity information/disparity displacement may be signaled within the data stream as has also been noted above.

[0086] One advantage of the embodiments outlined above is that they locate the portions to be copied out of the reference residual signal **63** of already coded views **20** via disparity displacement, such as disparity vectors, the derivation of which is completely based on already coded information, such as coded motion and disparity/depth information **42** and **60** or **34**d_1, without assuming any particular structure of the actual disparity field of the scene of the multi-view signal **12**. In particular, it is not assumed that the disparity field can be well approximated by a constant displacement-constant over the whole filed of view-which assumption would not mirror realistic scenes. Instead, actually coded disparity information, such as the disparity data **60**/**62** or the depth maps **34**d_1 of the reference view, are used for accessing the residual **63** of an already coded view such as the reference view **22**.

[0087] Furthermore, the embodiments outlined above allow that inter-view residual prediction is used for two types of blocks, namely blocks for which motion data **54**/**56** is derived based on motion data **42**/**46** in an already coded view, such as the reference view **20**, and blocks for which motion data **54**/**56** has been explicitly transmitted (for example, using spatial or temporal motion vector prediction or without such prediction). That is, the reference-view reconstructor **24** and the dependent-view reconstructor **28** may be configured to use motion compensated prediction so as to reconstruct the current pictures of the reference and dependent view, and the dependent-view reconstructor **26** may be configured to predict motion data **54**/**56** of the current picture of the dependent view **22**, underlying the motion compensated prediction, by locating corresponding positions in the current picture of the reference view **20** using the derived disparity displacement, and using the motion data for the current picture of the reference view **20** at the corresponding positions to predict the motion data **54**/**56** of the current picture of the dependent view. The dependent-view reconstructor **26** may then be configured to predict the residual signal of the current block of the current picture of the dependent view, remaining after motion compensated prediction using the predicted motion data, by copying a portion of the reference residual signal **63** of the current picture of the reference view, displaced from a location of the current block of the current picture of the dependent view **22** according to the disparity displacement (which had also been used for this block for inter-view motion data prediction.

[0088] The disparity displacement, such as the disparity vectors, which are used for accessing the reference residual signal **63**, can be defined with a sub-sample accuracy, in which case the inter-view residual prediction includes an interpolation of the already coded residual, i.e. the reference residual signal **63**, at sub-sample locations. That is, the dependent-view reconstructor **26** (and inter-view predictor **66**, respectively) may be configured to perform the block-granular disparity-compensated prediction using disparity vectors defined at sub-sample resolution.

[0089] Moreover, advantageously, the inter-view residual prediction may be supported for more than one block size.

[0090] In some embodiments of the invention, a disparity correction vector can be additionally included in the data stream **14** for such inter-view residual predicted blocks in

order to make the inter-view residual prediction more flexible. More generically speaking, the dependent-view reconstructor **26** (and inter-view predictor **66**, respectively) may be configured to refine a disparity displacement for a current block of the current picture of the dependent view **20** using an explicitly signaled disparity displacement residuum explicitly signaled within a multi-view data stream **14** (or **38**), and predict the residual signal of the current block of the current picture of the dependent view **20** by copying a portion of the reference residual signal **63** of the current picture of the reference view, displaced from a location of the current block of the current picture of the dependent view according to the refined disparity displacement.

[0091] Thus, the concept underlying the above embodiments and the possible variations outlined below can be decomposed into the following steps.

[0092] Derivation of depth/disparity data for the current picture of the current view.

[0093] Residual prediction using a derived disparity vector, and

[0094] Signaling the usage of residual prediction inside the data stream.

[0095] Regarding the latter signalization, it should be noted that naturally the interview residual prediction could alternatively be applied to every block, or the activation of the interview residual prediction could be determined in the same manner at encoder and decoder sides based on previously coded/decoded portions of the data stream in which cases no signalization would have to be provided.

[0096] In the following, the just-mentioned steps including embodiments are described in more detail. All steps are described for block-based coding and translational disparity vectors. The embodiments—also the above outlined embodiments—are, however, also applicable to more general schemes in which a generalized set of samples such as a non-rectangular part of a block, or any other shape, is associated with a unique set of disparity parameters for defining the disparity displacement. These embodiments are also applicable for coding schemes in which the disparity compensation of the residual is carried out using higher order motion models such as affine motion models, or N-parameter motion models.

[0097] In the following, different possible implementation details regarding inter-view residual prediction are described, such as, for example, the way as to how the disparity displacement based on which the residual prediction, such as the residual prediction signal **326'**, for a current block, such as block **50** or block **52**, is actually preformed, may be derived from a depth map estimate **64**, is described in more detail. In particular, it is assumed that the disparity displacement underlying this inter-view block-based disparity-compensated residual prediction is derived in the form of a disparity vector. That is, a block of a current picture in a particular view, such as view **22**, that is not the backwards compatible base view, such as **20**, is inter-view residual predicted using a disparity vector and while different embodiments for deriving such a disparity vector have been described above, the embodiments which will be described in the following, concern those embodiments where the derivation of the disparity vector is performed via the depth map estimate **64** the estimation of which as been described in accordance with variants of FIG. **1***c* and FIG. **1***d*. Details concerning the actual locating procedure within the reference residual signal **63** are also described.

[0098] That is, in the following description, we preliminarily assume that an estimate of the depth map already exists. With respect to FIG. **1***c* and FIG. **1***d* it has already been outlined as to how such estimate may be obtained. Later, we describe how this depth estimate can be derived in even more detail.

[0099] The depth data **64** for the current picture may either given by a pixel-wise or a block-wise depth map. If a pixel-wise depth map is given, the depth map specifies a depth value for each sample (or each luminance sample) of the associated picture. If a block-wise depth map is given, the depth map specifies a depth value for an M×N block of samples (or luminance samples) for the associated picture. For example, a depth value for each block of the smallest possible block size (e.g., 4×4 or 8×8 block) that can be used for motion compensation could be specified. Conceptually, a depth value d given by a sample of the depth map, specifies a function of the real-world depth z, which is the distance between the associated real-world object point (the projection of the real-world object point is the image sample at the given position) and the camera:

$$d=f_{dz}(z)$$

[0100] The depth values are given with a particular precision (furthermore, depth values are often estimated, since the actual depths are usually not known). In most cases, depth values are given by integer numbers. Given the depth values and particular camera parameters (such as the focal length, distance between cameras, minimum and maximum depth values, or functions of these parameters), the depth value d can be converted into a disparity vector $v=[v_x,v_y]^T$:

$$v(x)=f_{xd}(d(x),x)$$

where f_{vd} specifies the function that maps a depth value d at sample location x=[x,y] T to a disparity vector. In a particular important setup is the one-dimensional parallel camera configuration, which is characterized by the following properties:

[0101] all cameras of the camera array are of the same type and have the same focal length.

[0102] the optical axes of all cameras are parallel and lie inside the same plane.

[0103] the scan lines of the image sensors are parallel to the plane that contains the optical axes

[0104] In this case, the vertical component of the disparity vector is zero, $v=[v,0]^T$. Each real-world object point has the same vertical location in all views. Its horizontal location depends on the depth of the object point. The difference between the horizontal locations is given by the disparity

$$v=f_{vd}(d).$$

[0105] In an important case, the relationship between the real-world depth z and the depth values d is given in a way that a linear relationship between the disparity v and the depth value d is obtained

$$v = m_{vd}d + n_{vd},$$

where m_{vd} and ma and are given by the camera parameters. The depth values d are usually given as integer values. And for internal calculations it is usually also advantageous, if the obtained disparity values are integer values. For example, the disparity ^{v} can be expressed in the same units

that is used for the motion/disparity vectors in motion/disparity-compensated prediction (e.g., half-, quarter, or eighth-sample accuracy). In this case, the integer values for the disparity can be obtained by the integer equation

$$v = [(m) *_{vd} d + n *_{vd}) >> u_{vd},$$

where ">>" specifies a bit shift to the right (in two's complement arithmetic), and mvd and nvd are scaled (and rounded) versions of and, respectively.

[0106] Using the described basic relationships between the given depth values and the actual disparity, we describe embodiments for inter-view residual prediction using a disparity vector that is derived based on the given depth values (or estimate of the depth values) for the current picture of the current/dependent view **22**.

Derivation of the Residual Signal for a Coded Picture

[0107] In the following, an embodiment for deriving the above outlined reference residual **63** is described in more detail. In this section, it is assumed that the residual prediction in the form of block **310** is not used within the reference view coding path including reconstructor **24** and encoder **80**, although the details outlined below are easily transferable to this case. In other words, it is preliminarily assumed that the residual predictor **310** in FIG. **4** does not exist, in which case the output of inverse transformer **312** is directly connected to the second input of combiner **318** and the reference residual signal output **304**, respectively. Then, the subtracter **406** is also not present and the output of subtracter **404** is connected to transformer **408** directly.

[0108] In that case, the residual signal **412** for a block of the reference signal such as block **40** or **44**, is the difference between the original signal entering input **400** for the block, and the prediction signal **322** that is used for predicting this block. The residual signal **412/414** is coded using transform coding within transformer **408**, which includes quantization so that the reconstructed residual as obtained at the output of inverse transformer **312** is not equal to the difference between original and prediction signal as output by subtracter **404**. Thus, the reconstructed signal as output by combiner **318** such as obtained by adding the coded residual as output by inverse transformer **312** to the prediction signal **322**, is also not identical to the original signal input at input **400**. In order to obtain a residual picture for a given coded picture of the reference view **20**, the residual signals for the blocks **40/44** of the reference view are reconstructed by the inverse transformer such as by scaling and inverse transforming the transmitted transform coefficient levels **316**, and arranged to form a residual picture within which the inter-view predictor **330** locates the block/portion to be copied for an inter-view residual predicted block **50/52** of the dependent view using the disparity displacement derived for this block as outlined above and further below. This formed residual picture then forms the reference residual signal **63** passed on to the dependent-view reconstructor **26**.

[0109] In embodiments of the invention, the residual picture finally used for the reference residual signal **63**, is varied in that residuals as obtained by inverse transformer **312** for intra-coded blocks **40/44** are set equal to zero, since the residual for intra coded blocks has different characteristics and cannot be efficiently used for predicting the residual **324'** of interview residual prediction coded blocks **50/52**. In some embodiments of the invention, the residuals for the disparity-compensated blocks, i.e. blocks that are predicted using already coded pictures of even different views as a reference picture (this would be possible if the reference view **20** itself forms a dependent view of an even more basic underlying reference view), are set equal to zero additionally or alternatively. In other words, the reference-view reconstructor **24** may be configured to perform the reconstruction of the current picture of the reference view **20** of the multi-view signal **12** using block-based hybrid coding involving at least one intra or interview block coding mode and at least one temporal inter block coding mode, and the dependent-view reconstructor **26** may be configured to, in predicting the residual signal of the current picture of the dependent view **22** from the reference residual signal **63** of the current picture of the reference view, set the reference residual signal **63** to zero within blocks of the current picture of the reference view **20** of the intra or inter-view block coding mode. Out of this modified reference residual signal **63**, the residual signal prediction is then copied using the disparity displacement.

[0110] The generation of a particular residual block, i.e. the actual block copying, performed by inter-view predictor **330**, which residual block is then used for the inter-view residual prediction, can also be performed during the actual process of inter-view residual prediction, i.e. online on demand. That is, it is not necessitated that the complete residual picture, i.e. the residuums of all blocks of the current picture of the reference view in a format put together, as generated before another picture, such as the current picture of the dependent view, is coded/decoded.

Derivation of a Disparity Vector for a Given Block

[0111] In the following, it is assumed that a disparity vector is used to define the disparity displacement which specifies which portion out of the reference residual signal **63** of an already coded picture of another view is used for the inter-view residual prediction. In the following, different embodiments for obtaining such a disparity vector for a given block **50/52** are described.

[0112] In particular, firstly it is assumed that the inter-view predictor **330** has access to a depth map estimate in accordance with any of the variants of Figs. Ic and Id. As described above, the inter-view predictor **330** may alternatively determine the disparity vector in another way such as described above with respect to the other variants.

[0113] In an embodiment, first a representing depth value d of the given block **50/52** subject to inter-view residual prediction, is obtained by inter-view predictor **330** based on the given sample-based or block-based depth map **64**. In one embodiment, a particular sample location x of the given block, which may be the top left sample, the bottom right sample, a middle sample, or any other particular sample, such as any other set of corner samples, may be considered. The depth value d=d(x) that is associated with the sample (as given by the given block-wise or sample-wise depth maps **64**) is used as representing depth value. In another embodiment, two or more sample locations xi of the given block (for example, the corner samples or all samples) are considered and based on the associated depth values $d_i=d(x_i)$, a representing depth values d is calculated as a function of the depth values d_i. The representing depth value can be

obtained by any function of the set of depth values d_i. Possible functions are the average of the depth values di, the median of the depth values d_i the minimum of the depth values di, the maximum of the depth values di, or any other function. After obtaining the representing depth value d of the given block, the depth value is subject to a depth-to-disparity conversion within disparity estimator **28** so as to convert this depth value into a disparity vector $v=f_{v,d}(d)$, where the relationship between depth and disparity may be given by coded camera or conversion parameters which parameters may alternatively be set by default. In specific configurations, only horizontal displacements are possible and the depth can be estimated in a way that the depth value is equal to the horizontal displacement.

[0114] In another embodiment, a disparity correction vector is coded within the data stream such as within the prediction parameters **314'** and the disparity vector that is used for inter-view residual prediction by inter-view predictor **330** is obtained in the inter-view predictor **330** before use thereof, by adding the explicitly signaled and coded disparity correction vector as obtained from the prediction parameter **314'**, to the derived disparity vector derived, for example, from the disparity estimator **28** or from other disparity information contained within the prediction parameters **314'** as already outlined above. Namely, a disparity correction vector may, in accordance with a further embodiment, be coded and the prediction for the disparity vector for the current block to which the disparity correction vector is added, may be obtained by disparity estimator **28** by a spatial prediction using the disparity vectors of neighboring blocks **50/52** of the same time instant of the current/dependent view **22** and/or by a temporal prediction using the disparity vector of possibly co-located blocks in a temporal reference picture of view **22**. The block in a temporal reference picture may even be indicated by an explicitly coded motion vector so as to be used by inter-view predictor **330** to access the correct block within the temporal reference picture from which, in turn, the disparity vector is derived which, in turn, is used for accessing the appropriately positioned block/portion out of the reference residual signal **63**.

Residual Prediction for a Block Using a Derived Disparity Vector

[0115] Given the derived disparity vector for the current block **50/52**, the inter-view residual prediction, such as within inter-view predictor **330**, may be performed as follows. In particular, the location of the current block, i.e. the block **50/52** to be subject to inter-view residual prediction, is displaced by the determined disparity vector, and the residual block (with the same block size as the current block) at the displaced location in the reference view picture is used as residual prediction signal.

[0116] In order to explain the inter-view residual prediction derivation in more detail, reference is made to FIGS. **5***a* and **5***b*. FIG. **5***a,b* show the current picture **34***t*$_2$(T) of the dependent view, the reference residual signal, i.e. the reference residual picture, **500** for the current picture **32***t*$_1$(T) of the reference view and the estimated depth map **64**$_2$(T) for the current picture **34***t*$_2$(T) of the dependent view. As noted above, the residual picture **500** may be the residuum **324** which, when added to the prediction signal **322**, reveals the reconstruction of the current picture **32***t*$_1$.

[0117] The block within picture **34***t*$_2$(T) which is to be subject to inter-view residual prediction, is indicated at **502**. The content of the block **502** may have been predicted by any of the block coding modes in blocks **308'**a to **308'**c, or any combination thereof, with "combination" encompassing pixelwise adding as well as spatial subdivision. That is, although it is advantageous that the boundary of block **502** coincides with that of a block to which one coding mode is assigned, alternatively, different portions of block **502** may have been associated with different block coding modes. That is, the conding concept as described so far could also be modified to the extent that block **502** does not correspond to any of the blocks to which the individual coding modes are assigned, but to a block of a further subdivision which might be different from the block coding mode subdivision and is for deciding as to whether inter-view residual prediction is to be used or not.

[0118] In order to determine the portion/block **504** within the reference view **22** from which the residual signal for the current block **502** is to be predicted by inter-view disparity-compensated residual prediction, the location of the current block **502** is, frankly speaking, displaced by the determined disparity vector **506**, and thus block **504** represents a residual block out of the residual picture **500** for the current picture of the reference view **20**, having the same block size as the current block **502** and being displaced from a position co-located to the position of block **502** via disparity vector **506**. The location of block **508** is obtained as follows.

[0119] In the encoder, the derived residual prediction signal within block **504** is subtracted (such as by subtracter **406'**) from the original residual signal **412'** of the current block **502** which, in turn, is the difference between the original signal of block **502** and the prediction signal **322'** thereof as derived by, for example, motion/disparity-compensated prediction or intra prediction. The remaining signal, i.e. **414'**, is then coded, such as indicated above using transform coding including quantization.

[0120] At the decoder side, the coded residual signal **316** which is, as outlined above, exemplarily obtained by inverse scaling and transformation of the transmitted transform coefficient levels within data **316**, and the residual prediction signal **326'**, are added to the prediction signal **322'** derived by, for example, motion/disparity-compensated prediction or intra prediction, in order to obtain the reconstructed signal for the block **502** as output by the output of adder **318** in FIG. **3**.

[0121] The exact way of deriving the location of residual block **504** may be as follows. One or more first sample positions x are used to identify depth values within depth map estimate **64**$_2$(T), from which a representative disparity vector is determined, namely disparity vector **506**. This might be done by firstly looking-up the one or more depth values in map **64**$_2$(T) and then forming a common depth value therefrom such as by averaging. Then, a depth-to-disparity conversion is performed to obtain vector **506**. However, it would be possible to switch averaging and conversion. In order to apply the disparity vector **506**, another determination of a certain position of the current block **502** is performed such as a vertex thereof or the like. In FIG. **5***a* it's exemplarily the top-left sample. The position thereof in the reference view **20**, i.e. determined by the same coordinates, is used as a foot point for vector **506** which,

thus, determines the corresponding position of block **504**, i.e. here the top-left corner thereof, thereby determining the position of block **504**.

[0122] In one embodiment of the invention, sample-accurate displacement vectors **506** are used so that a sample of the reference residual **63**,**500** is directly used for predicting a sample of the current residual **326'**.

[0123] In another embodiment of the invention, sub-sample accurate displacement vector **506** (for example, quarter-sample accurate displacement vectors) are used. In this case, the residual prediction includes an interpolation of the reference residual signal **63**,**500**. A residual sample at non-integer locations may be found by filtering the surrounding residual samples in **63**,**500**. In one embodiment, the interpolation is performed in a way that only samples of a single transform block (a block of samples that was represented by a particular transformation) are used for generating a particular sample at a sub-sample location, i.e., the interpolation filter is not applied across transform boundaries of modules **312'** and **408'**. That is, as outlined above, the reference-view reconstructor **24** may be configured to, in reconstructing the current picture of the reference view **20**, use transform residual coding, wherein the dependent-view reconstructor **26** might be configured to, in predicting the residual signal of the current picture of the dependent view, apply an interpolation filter onto the reference residual signal **63** section-wise so as to not apply the interpolation filter across transform boundaries of the transform residual coding of the reference-view reconstructor.

[0124] In a further embodiment, the reference residual samples **63**, **500** are filtered before they are used for a prediction of the residual of a current block. As an example, such a filtering can be used for reducing the high-frequency (or low-frequency) components of the residual blocks. When a filtering is combined with the usage of sub-sample accurate displacement vectors **506**, the filtering can be performed before or after the interpolation (i.e., the original reference residual samples or the generated residual samples at non-integer locations can be filtered).

[0125] It is also possible that the residual prediction is not directly done in the spatial domain, but in the transform domain. i.e., the residual prediction signal **63** may be transformed and the resulting transform coefficients are added to the transform coefficients for the transmitted residual signal, then the final residual signal (which is added to the motion/disparity-compensated prediction signal) is obtained by an inverse transform of the accumulated transform coefficients. The transform of the residual prediction signal may include a quantization.

[0126] In that case, the inverse transformer **312'** would be positioned between the output of combiner **320'** and the input of combiner **318** instead of the position indicated in FIGS. **3** and **4**.

Signaling the Usage of Residual Prediction

[0127] In one embodiment of the invention, the usage of residual prediction can be adaptively chosen for a given block. Hence, the usage of residual prediction needs to be signaled to the decoder.

[0128] In one embodiment of the invention, a syntax element (for example, a flag) is included into the syntax for all motion/disparity-compensated blocks (but not for intra blocks) and indicates whether residual prediction is applied for the corresponding block. Intra-blocks are decoded without residual prediction. In another embodiment of the invention, the syntax element is only transmitted for motion-compensated blocks (but not for intra blocks and disparity-compensated blocks); whether a block is coded using motion or disparity compensation is signaled by the reference picture index or any other syntax element. If the syntax element indicating residual prediction is not transmitted, residual prediction is not used for the corresponding block.

[0129] In addition, the presence of the syntax element indicating residual prediction (and thus the possible usage of residual prediction) can be conditioned on any of the following (including all possible combinations):

[0130] The syntax element is transmitted only for a subset of the supported block sizes, for example, only for block that are larger or equal to a minimum block sizes.

[0131] The syntax element is transmitted only for particular coding mode. For example, the syntax element can only be transmitted for block that are not coded in a merge or skip mode.

[0132] The syntax element is only transmitted if the residual prediction signal contains at least a particular number of non-zero samples (for example, at least one non-zero sample). Or the syntax element is only transmitted if a transform and quantization of the residual prediction signal results in at least a particular number of transform coefficients.

[0133] Furthermore, the presence of the syntax element indicating residual prediction may depend on the motion hypotheses that are used for predicting the current block and the reference block or blocks. The reference block (or blocks) is (are) coded blocks in the reference view that are located in the reference view and cover at least one sample of the residual block that is used for residual prediction. That means, the reference blocks can be derived by displacing the location of the current block by the determined disparity vector v. The corresponding conditions for transmitting the residual signal may include any of the following:

[0134] The syntax element is only transmitted if a reference block is not intra coded.

[0135] The syntax element is only transmitted if a reference block is coded using motion-compensated prediction (using a temporal reference picture), or only motion-compensated prediction.

[0136] The syntax element is only transmitted if at least one of the employed reference pictures for the reference block has the same time instant as one of the reference pictures used for the current block. Instead of the time instant, similar measures such as the picture order count or the reference index (in combination with a reference list) can be used.

[0137] The syntax element is only transmitted if reference pictures of the same time instant are used for both the reference block and the current block. It means, neither the current nor the reference block refer to an access unit that is not used by the other block. Instead of the time instant, similar measures such as the picture order count or the reference index (in combination with a reference list) can be used.

[0138] The syntax element is only transmitted if the difference between the motion vectors that are used for a particular time instant (or picture order count, reference index) for the reference and the current block is less than or equal to a particular threshold. The motion

vector difference can be measured as a component-wise difference or the absolute value of the difference vector or any similar measure. As an example, the syntax element is only transmitted if both motion vectors are the same or only if the difference for each motion vector component is less than or equal to a quarter-sample.

[0139] Besides the transmission of a syntax element that indicates the usage of residual prediction, a disparity correction can be transmitted (see above). The transmitted disparity correction can consist of two components (a horizontal and a vertical component), or it can consist only of the horizontal component while the vertical component is inferred to be equal to 0. The presence of the disparity correction can depend on the value of the syntax element that indicates the usage of residual prediction. Furthermore, the presence of the disparity correction can also depend on the block size (for example, it is transmitted only for blocks larger than or equal to a particular size) or on the employed coding mode (for example, it may only be present for blocks that are not coded in a merge or skip mode).

[0140] The derivation of the inter-view residual prediction as described so far necessitates, in accordance with the above outlined variations regarding the derivation of the underlying disparity displacement in accordance with, for example, FIG. **1***c* and **1***d*, that an estimate **64** of the depth map for the current picture is available. As mentioned above, this depth map estimate **64** can specify a sample-wise depth map (a depth value is specified for each sample of the current picture) or a block-wise depth map (a depth value is specified for blocks of samples). The depth map estimate **64** may be derived based on already coded parameters, such as depth maps or disparity vectors and motion parameters. In principle, the possibilities for deriving a depth map estimate **64** for the current picture can be categorized into two classes. For one class, the depth map estimate is derived based on actually coded depth maps. The corresponding possibilities described below involve that the coded depth maps are present in the bitstream (before they are used). Concepts of the second class don't necessitate that depth maps are coded as part of the bitstream. Instead, the depth map estimate is derived based on coded disparity and motion vectors. The second class of procedures can be applied independently of whether depth maps are coded as part of a bitstream. Both cases discussed above with respect to FIGS. **1***c* and **1***d* for which the following description in so far provides individually transferable details regarding individual aspects. It should also be noted that, when depth maps are coded, both classes of methods can be applied. It is also possible to select different methods for different frames.

[0141] In the following, the basic concept and embodiments for deriving depth maps estimates (with and without coded depth maps) are described.

Class 1: Derivation Based on Coded Depth Maps

[0142] If the depth map that is associated with the current picture **32***t*$_2$(T) would be coded before the current picture, the reconstructed depth map could directly be used as an estimate of the real depth map for the current picture. It is also possible to pre-process the coded depth map (e.g., by applying a filtering it) and use the result of the pre-filtering as the estimate of the depth map that is used for deriving the disparity vector used for residual prediction.

[0143] In most configurations, the depth map that is associated with a particular picture is coded after the picture **32***t*$_2$(T) (often directly after the associated picture). Such a configuration allows that coding parameters (such as motion parameters) that are transmitted for coding the conventional video pictures can be used for predicting the coding parameters that are used for coding the depth maps, which improves the overall coding efficiency. But in such a configuration, the depth map that is associated with a picture cannot be used as an estimate for the depth map in deriving the disparity vector used for residual prediction. However, the depth map for an already coded view (of the same access unit) such as **20** is usually available and can be used for deriving an estimate of the depth map of the current picture. At least, the depth map of the base view (independent view) **20** is available before coding any dependent view **22**. Since the depth map of any view represents the geometry of the projected video scene to some extent (in combination with camera parameters such as focal length and the distance between cameras) it can be mapped to another view. Consequently, if the depth map for the current picture **32***t*$_2$(T) is not available, the coded depth map for an already coded view of the same access unit **20** is mapped to the current view and the result of this mapping is used as depth map estimate.

[0144] In the following we describe a particular algorithm for realizing this mapping. As described above, each depth value d corresponds to a displacement vector v between two given views. Given transmitted camera or conversion parameters, a depth value d can be converted to a displacement vector my the mapping $v=f_{vd}(d)$. Hence, given a depth value d at a particular sample location $_{XR}$ in the reference depth map (already coded), the sample location xc of the same depth value in the current depth map is obtained by adding the disparity vector to X_R, $_{XC}=_{XR+V}$. Hence, each depth value of the reference depth map can be mapped to a sample location of the current depth map in order to obtain a depth map estimate **64** for the current picture. However, since parts of objects that are visible in one view are not visible in another view, there are sample locations in the depth map for the current view **22** to which more than one depth values is assigned and there are sample locations in the depth map for the current view to which no depth values are assigned. These sample locations may be processed as follows:

[0145] If more than one depth value is assigned to a particular sample location, it means that a foreground object is displaced in front of a background object. Consequently, the depth value d (of the potential depth values) that represents the smallest distance to the camera is assigned to such a sample location.

[0146] If more no depth value is assigned to a particular sample location, it means that a foreground object has moved and the previously covered background is visible. The best that can be done for such regions is to assume that the disoccluded background has the same depth than the neighboring background samples. Hence, regions to which no depth value has been assigned are filled with the depth value of the surrounding samples that represents the largest distance to the camera.

[0147] This algorithm is specified in more detail in the following. For simplifying the following description, we assumed that larger depth values represent smaller distances

to the camera than smaller depth values (but the algorithm can easily be modified for the opposite assumption):

[0148] 1. All samples of the depth map (estimate) for the current picture are set to an undefined depth value (e.g., −1).

[0149] 2. For each sample location $_{XR}$ of the reference depth map, the following applies:

[0150] a. The depth value d at the sample location $_{XR}$ is converted to a disparity vector 1? using the given camera or conversion parameters, the disparity vector v is rounded to sample accuracy (if applicable), and the sample location inside the current picture is derived by $_{X}c=_{XR}+V=_{XR}+[\text{round}(f]_{vd}(d))$.

[0151] b. If the depth value at sample location $_{XC}$ in the current picture has an undefined value, the depth value at sample location is set equal to the depth value d.

[0152] c. Otherwise, if the depth value at sample location $_{XX}$ in the current picture has a defined value d_x, with dx<d, the depth value at sample location is modified and set equal to the depth value d.

[0153] 3. The regions in the current depth map that have undefined depth values are filled by a particular hole filling algorithm. For such a hole filling algorithm, the depth value of the background that is uncovered in the current view is derived based on the samples of the surrounding depth values. As an example, the smallest depth map value of the surrounding samples can be assigned. But more sophisticated hole filling algorithms are possible.

[0154] The algorithm for mapping a depth map of a given view to a different view is further illustrated in FIG. **6** on the basis of a very simple example. FIG. **6** illustrates a possible process for mapping a depth map such as $\mathbf{32}t_1(\text{T})$ given for one view **20** to another view **22**. At the left hand side, the given depth map for the reference view is shown, where the shaded area represents a background and the white area represents a foreground object; in the middle of FIG. **6**, middle, the converted depth map obtained by displacing the samples of the given map with the disparity vectors that correspond to the depth values and keeping the foreground object for locations to which more than one sample is projected, is shown. The black area represents on disoccluded area to which no sample has been projected. FIG. **6**, right, shows the converted depth map after filling the disoccluded areas by the depth value for the background, i.e. by background filling.

[0155] In a particular embodiment of the invention, the hole filling can realized by a particularly simple algorithm which processes the lines of the converted depth map separately. For each line segment that consists of successive undefined depth values, the two surrounding values are considered, and all depth samples of the line segment are replaced with the smaller of these two depth values (background depth). If the line segment has only one surrounding depth value (because it is located at the image border), the depth samples of the line segment are replaced with this value. If complete lines have undefined values after this process, the same process is applied for the columns of the depth map.

[0156] Although the algorithm above has been described for sample-wise depth maps, it can also be applied to block-wise depth maps (resulting in a lower complexity) or the given sample-wise depth map for the reference view can first be converted into a block-wise depth maps (by downsampling) and then the algorithm can be applied for the block-wise depth map.

Class 2: Derivation Based on Coded Disparity and Motion Vectors

[0157] If no depth maps are coded as part of the bitstream, an estimate for the depth map can be generated by using the coded motion and disparity vectors. A basic idea of the following concept can be summarized as follows. The decoding of a (multi-view) video sequence generally starts with a random access unit. The picture for the base view in a random access unit is intra coded without referencing any other picture. The pictures for dependent views in the random access unit can be intra coded or predicted using disparity-compensated prediction. Typically, most blocks will be coded by disparity-compensated prediction, since it usually gives better prediction results than intra prediction. Since, the coded disparity vectors (which are used for disparity-compensated prediction) can be converted into depth values (using the inverse function f_{vd}^{-1}) the disparity vectors can be directly used for generating a block-based depth map that is associated with a dependent view in a random access unit (the depth for intra-coded blocks can be estimated based on the depth for surrounding disparity-compensated block). Then, this obtained depth map can be mapped to the base view. The next picture for the base view is typically coded using mostly motion-compensated prediction. Here, it can be assumed that the motion of the depth data is the same as the motion for the texture information (a depth and an associated texture sample belong to the same object point). Given this assumption, the estimated depth data for the first picture in the base view can be motion-compensated for obtaining an estimate for the depth map of the base view in the current access unit. And then, this (motion-compensated) depth map estimate for the base view can be mapped to a dependent view for obtaining a depth map estimate for the current picture (in the current view). If more than two views are coded, the creation of depth map estimates for the third view, fourth view, etc. can be simplified, since we also have a depth map estimate for the first two views of the access unit. One of these depth map estimates (advantageously the base view) can be mapped to the third, fourth, or any following view in order to generate a depth map estimate for this view.

[0158] The idea of generating a depth map estimate is further illustrated by some figures (showing the processing steps for multi-view coding with two views as they are performed by depth estimator **28**). The coding/decoding starts with a random access unit, for which the base view picture $\mathbf{32}t_1(\mathbf{0})$ is intra-coded and the non-base-view pictures $\mathbf{32}t\mathbf{2}(\mathbf{0})$ are coded using only intra and inter-view prediction (but no motion-compensated prediction). After coding the second view **22** in the random access unit "0", a block-based depth map estimate for this second view **22** is generated **120** using the coded disparity vectors **122** for this view **22**, as illustrated in FIG. **7**. This depth map estimate $\mathbf{64}_2(\mathbf{0})$ for the second view **22** is then mapped **124** to the first view (base view) **20** and a depth map estimate $\mathbf{64}_1(\mathbf{0})$ for the first view **20** is obtained. It should be noted that for the second view **22** of a random access unit, no estimate of the depth map is available when the second view **22** of a random access unit is coded.

[0159] If a third view is coded, the depth map estimate of any of the first two views (advantageously the second view) can be mapped to the third view resulting in a depth map estimate for the third view, which can be used for deriving disparity vectors for the third view. And after coding the third view, a block-based depth map can be generated using the coded disparity vectors for the third view (which can than later be used for generating a depth map estimate for any following view). For any following view, basically the same process as for the third view can be used.

[0160] The pictures of the base view in non-random-access units are typically mainly coded by motion-compensated prediction, since motion-compensated prediction usually gives better coding efficiency than intra coding. After a picture of the base view is coded, an estimate of the depth map for this picture is generated **140** (cp. **71** in FIG. **1**) using the motion parameters **42**(**1**) for the picture $\mathbf{32}t_1(\mathbf{1})$, as illustrated in FIG. **8**. Therefore, each block of the new depth map estimate $\mathbf{64}_1(\mathbf{1})$ is created **140** by motion-compensating the depth map estimate $\mathbf{64}_1(\mathbf{0})$ (cp. **74** in FIG. **1**) for the corresponding reference picture or pictures. The reference pictures and corresponding motion vectors **42**(**1**) that are used are the reference pictures and motion vectors that are coded in the data stream for the associated picture. The depth samples for intra-coded blocks can be obtained by spatial prediction. This depth map estimate for the base view is than mapped **142** (cp. **76** in FIG. **1**) into the coordinate system for the second view in order to obtain a depth map estimate $\mathbf{64}_2(\mathbf{1})$ for the second view which can be used for deriving disparity vectors, i.e. to perform inter-view redundancy reduction.

[0161] For any further coded view, a depth map estimate can be generated by mapping the depth map estimate for any already coded view (base view, second view, etc.) to the corresponding view.

[0162] After actually coding the picture of the second view (or any following view), the associated depth map estimate can be updated **160** (cp. **77** in FIG. **1**) using the actually coded motion and disparity vectors, as illustrated in FIG. **9**. For blocks that are coded using disparity compensation (or for which disparity vectors or disparity correction vectors are transmitted), the depth map samples can be obtained by converting **162** the coded disparity vectors **60** to depth values as described above. For blocks that are coded using a motion-compensated mode, the depth samples can be obtained by motion compensating the depth map estimate for the reference frame $\mathbf{32}t_2(\mathbf{0})$. Or alternatively, a depth correction value, which is added to the current depth map estimate $\mathbf{64}_2(\mathbf{1})$, can be derived based on the coded motion parameters **42**(**1**) and **54**(**1**) for the current and for the reference view. The depth samples of intra coded blocks can be predicted using spatial prediction or using the motion parameters of neighboring blocks. After an updated depth map estimate **74** for the second view has been generated, this depth map estimate **74** is mapped **164** (cp. **78** in FIG. **1**) to the base view **20** for obtaining a depth map update $\mathbf{64'}_1(\mathbf{1})$ (cp. **74** in FIG. **1**) for the base view **20**.

[0163] If more than two views are coded, the depth map update process for these views is the same as for the second view. However, the base view depth map is only updated after the second view has been coded.

[0164] The motion compensation operations for depth maps can be performed using the coded sub-sample accurate motion vectors. It is, however, often advantageous (from a complexity as well as coding efficiency point of view), if the motion compensation operations for depth maps are performed with sample (or even block) accuracy. Therefore, the actually coded motion vectors are rounded to sample or block accuracy and these rounded vectors are used for performing the motion compensation. Furthermore, the described concept can be applied for sample-wise as well as block-wise depth map estimates. The advantage of using block-based depth maps is a lower complexity and memory requirement for all processing steps. With block-based depth maps, each depth sample represents the depth for a block of samples of the associated picture (e.g., 4×4 blocks or 8×8 blocks). All described operations can be performed for block-based depth maps in a straightforward way (i.e., by simply considering a lower resolution of the depth maps-one depth sample just represents multiple instead of one texture sample).

Besides the mapping of a given depth map from one view to another (which has been described above), the algorithm contains the following basic steps:

[0165] Creating a depth map based on disparity vectors for a picture of a random access unit.

[0166] Temporal prediction of the base view depth map using the motion parameters of the associated picture.

[0167] Update of a depth map estimate using actually coded motion and disparity vectors for the associated picture.

Particular embodiments for these algorithmic steps are described in the following.

Creation of a Depth Map for a Picture in a Random Access Unit

[0168] In a particular embodiment of the invention, the creation of a depth map for a picture of a dependent view in a random access unit proceeds as follows. In general, such a picture contains blocks that are coded using disparity-compensated prediction as well as blocks that are intra coded. First, all blocks that are coded using disparity-compensated prediction are considered. The disparity vectors are converted into depth values and these depth values are assigned to the corresponding samples of the depth map. If two or more motion hypotheses are used, either one hypothesis is selected or the final depth value is set equal to a function of the depth values for the individual motion hypotheses (for example, the average, the median, the maximum, or the minimum). After assigning the depth values for all disparity-compensated blocks, the depth values for intra coded blocks are obtained by spatial intra prediction. In one version, these samples can be obtained by using the same intra prediction modes that are used for the associated texture picture. In another version, the depth of an intra-block can be set equal to a depth values that is obtained by a weighted average of the surrounding samples (or blocks), where the weighting factors can be determined based on the used intra prediction modes. In a further version, the depth for an intra-block can be obtained by setting the depth samples equal to a value that is given by a particular function of the surrounding intra samples (e.g., the average, the median, the maximum, the minimum). Other spatial prediction algorithms are also possible. The depth assignment for intra-coded blocks can also be done inside a single loop over the blocks in an image. That means, the blocks are processed in a particular order (e.g., the coding order), and for both disparity-compensated and intra blocks, the depth values are

generated in this order (i.e., the depth assignment for intra-coded blocks doesn't need to wait until all disparity-compensated blocks are processed).

Temporal Prediction of the Base View Depth Map

[0169] In general, pictures of the base view contain motion-compensated blocks and intra coded blocks. The depth values for motion-compensated blocks are derived by motion-compensated prediction of the depth map estimate for the corresponding reference picture. If a block of the texture picture is coded using a single motion hypothesis, the depth samples for this block can be obtained by displacing the depth samples of the depth map estimate for the reference picture (given by the signaled reference index) by the transmitted (or inferred) motion vector. This motion compensation operation can be performed with the accuracy of the transmitted motion vectors (which is usually a sub-sample accuracy) or with sample-or block-accurate motion vectors. If the motion compensation is performed with sub-sample accuracy, an interpolation filter is applied for generating the samples at sub-sample positions. If the motion compensation is performed with sample or block accuracy, the transmitted motion vectors are rounded before they are used. If the block of the associated picture is coded with more than two motion hypothesis, one of the hypotheses can be selected for motion compensation of the depth maps, or all motion hypotheses are used by generating the final depth map estimate for the block as a weighted sum of the depth prediction signals for the individual motion hypotheses. Furthermore, the depth samples for a block of a given sizes can be set equal to a representing depth. This representing depth can be obtained by selecting a particular location inside the block and deriving the depth value for this location using motion compensation, or it can be obtained by defining a function of the motion- compensated depth values for this block. Such a function can be the average of the depth samples, or the median of the depth samples, or the minimum or maximum of the depth samples, or the depth sample value that occurs most often in the block.

Update of a Depth Map Using the Coded Motion and Disparity Parameters

[0170] As mentioned above, the depth map estimate for a picture can be updated after coding the picture. In the following, we describe some embodiments of such an update algorithm. Blocks of the picture are processed in a particular order (for example, the coding order) and for each block, the following applies:

[0171] If the block has been intra-coded (in the associated texture picture), the depth sample values for this block can be derived by spatial prediction using the samples of neighboring block. Some examples for such a spatial prediction technique have been described above. The depth sample values can also be obtained by motion compensation using the motion parameters of a neighboring block (see the description for motion-compensated blocks below). It is sometime advantageous, if the intra block are processed after all motion- and disparity-compensated blocks are processed, because then more neighboring are available and can be used for spatial prediction of depth samples or motion parameters.

[0172] Otherwise, if the block is coded using one or more disparity vectors (disparity hypotheses), the depth samples are derived by converting the disparity vectors to depth values. If only one disparity vector (disparity hypothesis) is used for the block, the depth value if given by the corresponding disparity vector. If two or more disparity vectors are used for the block, one of the disparity vectors can be selected for deriving the depth value, or for each disparity vector a depth value can be derived and the finally assigned depth value is obtained by applying a function of the individually derived depth values. Possible functions are, among others, the minimum or maximum of the individual depth values, the median of the depth values, the average of the depth values, or the depth values that occurs most often.

[0173] Note that a block that is coded using a disparity vector may additionally be associated with a temporal motion vector. In this case, the temporal motion vector can be ignored. Or the derived depth values can be combined with depth values that are derived for temporal motion hypotheses (see below) in any specific way (e.g., by averaging these two signals).

[0174] The disparity vector based depth estimation can also be used if a disparity vector or a disparity vector correction has been coded for updating/refining the derived disparity vector used for residual prediction.

[0175] Otherwise, the block is coded using only temporal motion hypotheses and the temporal motion hypotheses are used for updating the depth samples for the block.

[0176] In a first embodiment of the invention, the depth map samples are derived by straightforward motion compensated prediction using the depth map estimates associated with the reference pictures for the current view. This motion compensation operation can be realized by any of the embodiments for temporal prediction of the base view depth map described above.

[0177] In a second embodiment of the invention, the depth map samples are not simply motion compensated, but instead a depth correction value is derived based on the motion vector coded for the current view and the motion vector coded for the corresponding block in the reference view and this depth correction value is added to the depth map estimated in order to obtain an updated depth map estimate. The advantage of such an approach is that depth changes between two instances can be considered.

[0178] Let d_{prd} be the current depth estimate for a sample or a block, let m_{mcurr} be the motion vector that is actually used for motion-compensation of the current block, and m_{re} be the motion vector for the reference block in the reference view (the reference block is derived by using a disparity vector given by the depth estimate d_{prd} as described above). Furthermore, let $'v_{t-1}$ be the disparity vector in the reference access unit and let v_t be the disparity vector in the current access unit. Given the basic equation for the interrelationship between the motion and disparity vectors that we derived in the beginning of the description (see illustration in FIG. **10** for s single sample),

$$m_{curr} + v_{t-1} - m_{ref-Vt} = 0,$$

the current disparity vector can be set equal to

$$v_t = v_{t-1} + (m_{curr} - m_{ref}),$$

[0179] if we assume that the coded motion parameters and the disparity in the reference picture are correct. The disparity vector can be converted into a depth and vice versa. Hence, the current depth can be expressed as

$$d = d_{t-1} + f_{vd}^{-1}(m_{curr} - m_{ref}),$$

[0180] The depth d_{t-1} is the depth value given in the reference image, it can be accessed using the motion vector for the current block. It is also possible to replace the depth in the reference image with the current estimate for the depth d_{prd}, since this depth has been derived using motion compensation from the depth in a reference image.

[0181] We showed the basic concept for obtaining an updated depth value using the motion vectors of the current and the reference block. This basic concept can be used in a variety of actual implementations. For example, if more than one motion vector is used for the current block and/or the reference block, a single motion vector can be selected or different depth values can be derived for the different motion vector and the final depth is obtained by using the average (or any other function) of the individually derived depth values. Furthermore, only those motion hypotheses in the current and the reference block should be considered that use the same reference access unit (or reference time instant, or reference picture order count, or reference index). If such motion hypotheses don't exist, the conventional motion compensation process described above can be used or the depth sample can be marked as not available and are later replaced by suitable post-processing steps. Furthermore, the new depth value can be derived based on a single sample for a block, or for all samples of a block, or for a selected subset of the samples of a block. When different depth values for different samples are derived, separate depth values can be assigned for different regions of the current block (e.g., for all 4'4 blocks inside the current block), or the different depth values are used for deriving a representing depth for the entire block, e.g., by using the average, the median, the minimum, the maximum value, or the depth values that occurs most often. The depth map update process can also be combined with some pre-processing steps. For example, not available depth values can be replaced by the depth values of neighboring samples or blocks.

[0182] The above embodiments thus enable reducing the bit rate associated with coding residuals in multiview video coding applications by employing the residual data coded in one view for an efficient coding of the residuals for other views. These embodiments are applicable to multiview video coding with two or more views and for multiview video coding with and without depth maps. According to these embodiments it is possible to re-use the coded resiudal in one view for efficiently coding the residual in another view. Since all views represent the same video scene, the changes of sample values from one frame to another are similar for different views and this effect can be exploited for an efficient coding of dependent view. The above embodiments describe a concept for efficiently employing the residual of already coded views for following views, by using estimated or coded depth data. In accordance with some embodiments, the motion data that are coded in one view, is additionally used for predicting the motion data of other views.

[0183] Favorably, the above embodiments enable to use the concepts of inter-view motion and residual prediction independently of each other. In rate-distortion sense, the coding efficiency can be usually improved when different tools can be independently selected. For blocks for which the derivation of motion parameters from a reference view works well, an additional residual prediction may decrease the coding efficiency (i.e., it may increase a cost measure $D+\lambda R$,, or in other words increases the distortion for a given rate, or increases the rate for a given distortion). Or for blocks for which the residual prediction from a reference view improves the coding efficiency, an additional derivation of motion parameters based on the reference view may decrease the coding efficiency.

[0184] Moreover, the above embodiments enable to use sub-sample accurate vectors. Same can potentially increase the coding efficiency (when it is combined with a better model for the disparity in a picture). Finally, the above embodiments are combinable with the usage of blocks of different block size. Recent investigations (see the development of HEVC) have shown that the provision of multiple block sizes can significantly increase the coding efficiency, and that's why it could be advantagous to provide residual prediction for different block sizes. In particular, the new video coding standardization project of the ITU-T and ISO/IEC JTC 1/WG 11, which is also referred to as HEVC, shows very promising improvements in conventional 2-d video coding technology. The current working draft of HEVC provides substantial coding gains compared to ITU-T Rec. H.264 I ISO/IEC 14496-10. For achieving these gains several concepts have been extended in comparison to ITU-T Rec. H.264 I ISO/IEC 14496-10, and the above described approach for using the residual data of a different view for predicting the residual of the current view cannot be straightforwardly applied to the HEVC design. On the other hand, these techniques have to compete with the improved residual coding in HEVC. The main improvements in the area of residual coding include:

[0185] While the blocks sizes that are used for motion-compensated prediction in ITU-T Rec. H.264 I ISO/IEC 14496-10 range from 4×4 to 16×16 luma samples, a much larger variety of blocks sizes is supported in HEVC, which ranges from 4×4 to 64×64 luma samples. In addition, the basic coding units are not given by fixed macroblock and sub-macroblocks, but are adaptively chosen. The largest coding unit is typically a block of 64×64 luma samples, but the largest block size can actually be signaled inside the bitstream. The splitting of a block into subblock can establish a subdivision hierarchy of 4 or more levels. Furthermore, a block that is used for prediction can be further split into multiple transform blocks for the purpose of residual coding. Here, a hierarchy of multiple levels is supported.

[0186] Different transform sizes ranging from 4×4 to 16×16 transforms are supported.

[0187] The entropy coding of transform coefficients has been improved.

[0188] Although some aspects have been described in the context of an apparatus, it is clear that these aspects also

represent a description of the corresponding method, where a block or device corresponds to a method step or a feature of a method step. Analogously, aspects described in the context of a method step also represent a description of a corresponding block or item or feature of a corresponding apparatus. Some or all of the method steps may be executed by (or using) a hardware apparatus, like for example, a microprocessor, a programmable computer or an electronic circuit. In some embodiments, some one or more of the most important method steps may be executed by such an apparatus.

[0189] Depending on certain implementation requirements, embodiments of the invention can be implemented in hardware or in software. The implementation can be performed using a digital storage medium, for example a floppy disk, a DVD, a Blu-Ray, a CD, a ROM, a PROM, an EPROM, an EEPROM or a FLASH memory, having electronically readable control signals stored thereon, which cooperate (or are capable of cooperating) with a programmable computer system such that the respective method is performed. Therefore, the digital storage medium may be computer readable.

[0190] Some embodiments according to the invention comprise a data carrier having electronically readable control signals, which are capable of cooperating with a programmable computer system, such that one of the methods described herein is performed.

[0191] Generally, embodiments of the present invention can be implemented as a computer program product with a program code, the program code being operative for performing one of the methods when the computer program product runs on a computer. The program code may for example be stored on a machine readable carrier.

[0192] Other embodiments comprise the computer program for performing one of the methods described herein, stored on a machine readable carrier.

[0193] In other words, an embodiment of the inventive method is, therefore, a computer program having a program code for performing one of the methods described herein, when the computer program runs on a computer.

[0194] A further embodiment of the inventive methods is, therefore, a data carrier (or a digital storage medium, or a computer-readable medium) comprising, recorded thereon, the computer program for performing one of the methods described herein. The data carrier, the digital storage medium or the recorded medium are typically tangible and/or non-transitionary.

[0195] A further embodiment of the inventive method is, therefore, a data stream or a sequence of signals representing the computer program for performing one of the methods described herein. The data stream or the sequence of signals may for example be configured to be transferred via a data communication connection, for example via the Internet.

[0196] A further embodiment comprises a processing means, for example a computer, or a programmable logic device, configured to or adapted to perform one of the methods described herein.

[0197] A further embodiment comprises a computer having installed thereon the computer program for performing one of the methods described herein.

[0198] A further embodiment according to the invention comprises an apparatus or a system configured to transfer (for example, electronically or optically) a computer program for performing one of the methods described herein to a receiver. The receiver may, for example, be a computer, a mobile device, a memory device or the like. The apparatus or system may, for example, comprise a file server for transferring the computer program to the receiver.

[0199] In some embodiments, a programmable logic device (for example a field programmable gate array) may be used to perform some or all of the functionalities of the methods described herein. In some embodiments, a field programmable gate array may cooperate with a microprocessor in order to perform one of the methods described herein. Generally, the methods are performed by any hardware apparatus.

[0200] While this invention has been described in terms of several advantageous embodiments, there are alterations, permutations, and equivalents which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and compositions of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.

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What is claimed:

1. A method for reconstructing a multi-view signal coded in a data stream, comprising:

identifying a reference-view coding block in a picture of a reference view of a multi-view signal based on a disparity vector, wherein the disparity vector represents a disparity between the reference-view coding block and a dependent coding block in a picture of a dependent view of the multi-view signal;

obtaining a reference-view residual signal associated with the reference-view coding block, wherein the reference-view residual signal represents a difference between the reference-view coding block and a prediction of the reference-view coding block;

estimating a dependent-view residual signal for the dependent coding block in the picture of the dependent view based on the reference-view residual signal using the disparity vector, wherein the dependent-view residual signal represents a difference between the dependent coding block and a prediction of the dependent coding block;

adding a remaining signal corresponding to the dependent-view residual signal to the estimated dependent-view residual signal to obtain a reconstructed dependent-view residual signal; and

reconstructing the dependent coding block based on the reconstructed dependent-view residual signal and a prediction of the dependent coding block.

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