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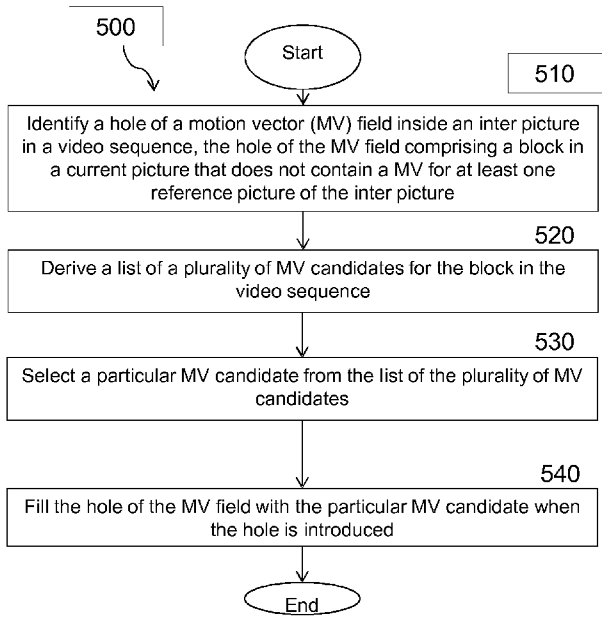

FIGURE 12

(57) Abstract: According to certain embodiments, a method for improved motion vector (MV) prediction includes identifying a hole of a MV field inside an inter picture in a video sequence. The hole of the MV field comprises a block in a current picture that does not contain a MV for at least one reference picture of the inter picture. The method includes deriving a list of a plurality of MV candidates for the block in the video sequence, selecting a particular MV candidate from the list of the plurality of MV candidates, and filling in the hole of the MV field when the hole is introduced.

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IMPROVED MOTION VECTOR PROTECTION

TECHNICAL FIELD

Certain embodiments of the present disclosure relate, in general, to video coding and more particularly to improved motion vector protection.

BACKGROUND

Most existing video coding standards use block-based prediction and transform coding. Pictures in a “to-be-encoded” video sequence are divided into small blocks as base units for prediction. There are mainly two types of prediction, spatial prediction, and temporal prediction. For video sequences that are captured by camera in real-life, it is likely that redundant information exists either within a picture or across several pictures. The motivation of the two prediction methods is to exploit those redundancies in different dimensions to reduce the size of the video.

Spatial prediction, known as intra prediction, removes redundancy in the spatial dimensions. It predicts a block using the previous decoded blocks within the current picture. A picture consisting of only intra-predicted blocks is referred to as an intra picture.

Temporal prediction, known as inter prediction, removes redundancy in temporal dimension. It predicts blocks of the current picture using blocks from previous decoded pictures. The previous decoded pictures that are used for prediction are referred to as reference pictures. The location of the referenced block inside the reference picture is indicated using a motion vector (MV). Each MV consists of x and y components which represents the displacements between current block and the referenced block in x or y dimension.

FIGURE 1 illustrates an example MV. Specifically, FIGURE 1 is a MV for the current block C. To capture the displacement more accurately, the MVs can point to the fractional sample positions in the reference picture. Those fractional samples are generated from the nearby integer samples using interpolation, which could be viewed as a weighted averaging process. A picture that allows inter-predicted blocks is referred to as an inter picture.

Inter pictures may have several reference pictures. These reference pictures are usually grouped into two reference picture lists, list 0 and list 1. The reference pictures that display before the current picture are grouped into list 0. The reference pictures that display after the current picture are grouped into list 1.

Inter predicted blocks can have two prediction types, uni- and bi-prediction. FIGURE 2 illustrates example uni- and bi- prediction. Uni-prediction is achieved by predicting from one block in one reference picture. Bi-prediction is achieved by predicting from two blocks in one or two reference pictures. The corresponding prediction block is a blending of the two reference blocks. The default blending method in HEVC takes the average of the two blocks.

In practice, for an encoder to decide the MV for the current block, the encoder would search for the best prediction block within the reference picture that yields the smallest Rate-Distortion (RD) cost. The RD cost is calculated as $D + \lambda * R$. The D (Distortion) measures the similarity between the prediction block and current block. A common metric for calculating D is the sum of absolute difference $SAD = \sum_{x,y} |P_A(x,y) - P_B(x,y)|$, where the P_A and P_B are the pixel values in the two block A and B respectively. The R (Rate) is usually an estimation of the final bits to be spent on encoding the corresponding MV. The λ is a trade-off parameter between R and D.

When the best prediction block is found, its corresponding MV information needs to be signaled in the bitstream. This is achieved using MV prediction technique. The technique first generates a list of MV candidates from some predefined neighboring positions, and then chooses one of the candidates to be the predictor for the current MV. The rationale is that the MV field inside a certain spatial or temporal region tends to be consistent and correlated. FIGURE 3 illustrates possible spatial positions for fetching neighboring MVs. Specifically, FIGURE 3 shows the spatially neighboring positions: left (L), top(T), top-right(TR), left-bottom (LB) and top-left (TL).

The availability of neighboring MVs directly impacts the performance of MV prediction. Unfortunately, there are some types of blocks which introduce discontinuities or “holes” to the MV fields which negatively affects MV prediction efficiency. One of them is intra blocks. The presence of an intra block would cause the previous relevant MVs to be forgotten and be unavailable for future prediction.

FIGURE 4 illustrates intra blocks breaking the continuity of MV inside an inter picture. As depicted, the current block has only intra spatial neighbors and is forced to use the default

(0, 0) as MV predictor which results in delta MV = (1, 2). If the previous MV (1, 3) would be made available, then delta MV becomes (0, -1) which is cheaper to be signaled.

The MV field discontinuity issue may also be introduced by uni-predicted inter blocks inside a B-picture. As uni-predicted inter blocks only contains MV for one direction, the previous MV for the other direction will not be carried on even though it might be very relevant for future inter blocks.

FIGURE 5 illustrates a uni-predicted inter block breaking continuity of MV inside a B-picture. In the current MV prediction scheme, MV (-4, -5) would be scaled to (4, 5) for predicting the current MV. That gives a delta MV = (-5, -6). If the previous MV (-1, -1) would be made available, then delta MV becomes (0, 0).

There currently exist certain challenges. For example, the presence of intra blocks or uni-predicted inter blocks breaks MV field continuity and introduces penalties to the MV prediction of future inter blocks.

SUMMARY

Certain aspects of the present disclosure and their embodiments may provide solutions to these or other challenges by proposing two schemes for countering the motion vector (MV) discontinuity introduced by intra blocks or uni-predicted inter blocks.

According to certain embodiments, a method for improved motion vector (MV) prediction includes identifying a hole of a MV field inside an inter picture in a video sequence. The hole of the MV field comprises a block in a current picture that does not contain a MV for at least one reference picture of the inter picture. The method includes deriving a list of a plurality of MV candidates for the block in the video sequence, selecting a particular MV candidate from the list of the plurality of MV candidates, and filling in the hole of the MV field when the hole is introduced.

According to certain embodiments, a device for improved MV prediction includes memory storing instructions and processing circuitry operable to execute the instructions to cause the device to identify a hole of a MV field inside an inter picture in a video sequence. The hole of the MV field comprises a block in a current picture that does not contain a MV for at least one reference picture of the inter picture. A list of a plurality of MV candidates is determined for the block in the video sequence. A particular MV candidate form the list of the plurality of MV candidates, and the hole of the MV field is filled in when the hole is introduced.

According to certain embodiments, a method for improved MV prediction includes identifying a hole of a MV field in a video sequence when encoding or decoding a current block of the video sequence. The hole of the MV field includes a previously encoded or decoded block in the video sequence that does not contain a MV. The hole of the MV field is counted by increasing a search range for fetching at least one neighboring MV used to predict a candidate MV for the previously encoded or decoded block.

According to certain embodiments, a device for improved MV prediction includes memory storing instructions and processing circuitry operable to execute the instructions to cause the device to identify a hole of a MV field in a video sequence when encoding or decoding a current block of the video sequence. The hole of the MV field includes a previously encoded or decoded block in the video sequence that does not contain a MV. The hole of the MV field is counted by increasing a search range for fetching at least one neighboring MV used to predict a candidate MV for the previously encoded or decoded block.

Certain embodiments may provide one or more of the following technical advantage(s). As an example, an advantage of certain embodiments may include improved compression efficiency from better MV prediction. As another example, an advantage of certain embodiments may include improved subjective quality for inter pictures. For example, certain embodiments may alleviate penalties on MV prediction so that more blocks can be coded using inter mode, which may reduce the intra flicking artefacts.

Certain embodiments may include none, some, or all of these advantages. Certain embodiments may include other advantages, as would be understood by a person having ordinary skill in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the disclosed embodiments and their features and advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

FIGURE 1 illustrates an example motion vector (MV);

FIGURE 2 illustrates example uni- and bi- prediction;

FIGURE 3 illustrates possible spatial positions for fetching neighboring MVs;

FIGURE 4 illustrates intra blocks breaking the continuity of MV inside an inter picture;

FIGURE 5 illustrates a uni-predicted inter block breaking continuity of MV inside a B-picture;

FIGURE 6 illustrates an example of right and bottom pixels in a 4x4 block with corresponding weights, according to certain embodiments;

FIGURE 7 illustrates a faster jumping approach, according to certain embodiments;

FIGURE 8 illustrates an example method for improving MV prediction, according to certain embodiments;

FIGURE 9 illustrates an example method for countering the hole when the hole is first introduced, according to certain embodiments;

FIGURE 10 illustrates another example method for countering the hole when encoding or decoding a future inter block, according to certain embodiments;

FIGURE 11 illustrates an example virtual computing device for improving MV prediction, according to certain embodiments;

FIGURE 12 illustrates another method for improved MV prediction, according to certain embodiments;

FIGURE 13 illustrates another example virtual computing device for improving MV prediction, according to certain embodiments;

FIGURE 14 illustrates another method for improved MV prediction, according to certain embodiments;

FIGURE 15 illustrates another example virtual computing device for improving MV prediction, according to certain embodiments;

FIGURE 16 illustrates an exemplary network node, in accordance with certain embodiments;

FIGURE 17 illustrates an exemplary wireless device, in accordance with certain embodiments;

FIGURE 18 illustrate an example network node, according to certain embodiments; and

FIGURE 19 illustrates an exemplary radio network controller or core network node, in accordance with certain embodiments.

DETAILED DESCRIPTION

Certain aspects of the present disclosure and their embodiments may provide solutions to these or other challenges by proposing schemes for countering the motion vector (MV) discontinuity introduced by intra blocks or uni-predicted inter blocks. Specifically, according to certain embodiments, the schemes counter the holes of MV fields inside a picture. It is achieved by either filling in the holes when they are introduced or by jumping through the holes when the previous MVs are needed.

For example, according to a first scheme, a MV for each intra or uni-predicted inter block may be selected and stored. For future inter blocks, the stored MV can be used for prediction. As another example, according to a second scheme, the search range for fetching the neighboring MVs may be increased to consider new neighboring positions that are not necessarily the closest. Accordingly, there are, proposed herein, various embodiments which address one or more of the issues disclosed herein.

According to certain embodiments, a method is provided for improved motion vector (MV) prediction in a transmitter. The method includes identifying a hole of a motion vector field inside a picture in a video sequence and countering the hole of the MV field.

According to certain embodiments, a method is provided for countering the hole of the MV field when the hole is introduced. The method includes deriving a list of MV candidates for a block of pictures in the video sequence. A MV candidate may be selected from the list and stored. The MV candidate may be used for prediction in at least one future inter block.

According to certain embodiments, a method is provided for countering the hole of the MV field by jumping through the hole when encoding or decoding a future inter block. The method includes increasing a search range or the allowed positions for fetching one or more neighboring MVs.

According to certain embodiments, a transmitter is provided for improved MV prediction. The transmitter includes a memory storing instructions and processing circuitry operable to execute the instructions to cause the transmitter to perform the methods for improved MV prediction.

According to certain embodiments, a receiver is provided for improved MV prediction. The receiver includes a memory storing instructions and processing circuitry operable to execute the instructions to cause the transmitter to perform the methods for improved MV prediction.

According to certain embodiments, an encoder is provided for improved MV prediction. The encoder includes a memory storing instructions and processing circuitry operable to execute the instructions to cause the transmitter to perform the methods for improved MV prediction.

According to certain embodiments, a decoder is provided for improved MV prediction. The decoder includes a memory storing instructions and processing circuitry operable to execute the instructions to cause the transmitter to perform the methods for improved MV prediction.

Particular embodiments are described in FIGURES 1-15 of the drawings, like numerals being used for like and corresponding parts of the various drawings.

According to certain embodiments, a first scheme may be used to fill in the MV holes when the MV holes are introduced. Thus, the scheme is invoked directly after encoding or decoding the block that introduces such a hole. According to a particular embodiment, the scheme consists of deriving a list of MV candidates for the block, selecting one of them, and storing it to allow future inter blocks to utilize it for prediction. Thus, in this manner, a MV for each intra or uni-predicted inter block may be selected and stored for use for prediction for future inter blocks.

According to certain embodiments, the derivation of MV candidates list may follow the general neighboring MV derivation process. Regarding how to select the desired one for storing, according to a particular embodiment, an approach is to select the first candidate inside the list for simplicity.

According to another embodiment, selection schemes may be applied to decide the MV candidates for storing. According to a particular embodiment, for example, one possible scheme includes choosing the MV that is closest to the average of all the neighboring candidates. In another example embodiment, motion compensation may be applied for each candidate. The candidate that results in the smallest difference between the motion-compensated block and the current block's reconstruction may be selected. To compare the difference, metrics like SAD or SATD could be considered, in particular embodiments.

According to certain embodiments, pixels that are close to the right and bottom boundaries may be emphasized. FIGURE 6 illustrates an example of right and bottom pixels in a 4x4 block with corresponding weights, according to certain embodiments. The pixels indicated with the circles correspond to the right and bottom boundaries and might be more related to the pixels of the future blocks. According to a particular embodiment, only those pixels may be used for comparing the difference. Alternatively, higher weights may be assigned to the differences coming from those pixels. One benefit of only considering some pixels is that fewer pixels are needed and the generation of those pixels may be skipped during motion compensation.

For uni-predicted inter blocks, in additional to the abovementioned approaches, one may scale the MV of the current block to the other direction and then select the MV inside the candidate list that differs the most from this scaled MV.

According to the second proposed scheme for countering the holes of MV fields inside a picture, the second scheme includes jumping through the MV holes when encoding or decoding a future inter block. In other words, the scheme increases the search range or the allowed positions for fetching the neighboring MVs to consider new neighboring positions that are not necessarily the closest. This approach may provide larger gains compared to the first scheme. However, it is slightly more complex.

A particular embodiment, for example, includes tracing all the previous inter coded blocks in inverse decoding order. For each of encountered block, its spatial distance to the current block may be calculated. The MV from the block that is closest to be the additional candidate for predicting current MV may be selected. Additionally or alternatively, one may prioritize MVs with signs that they might be better to use for prediction than the other MVs. For example, one sign may be that the encountered inter block does not contain any residual information. The idea is that good MVs would give good predictions. Thus, such an approach requires less or no residual information to be encoded.

A simplified approach would be to include the candidates that are closest in terms of straight horizontal or straight vertical spatial distance, respectively. As when inversely tracing the blocks in horizontal or vertical direction, it is certain that the encountered block would be at its block boundary. Thus, using the corresponding block’s width or height information would make it possible to jump through several columns or lines for faster fetching.

FIGURE 7 illustrates a faster jumping approach. According to certain embodiments, a threshold on the distance of tracing back may be imposed since it is likely that the relevance of MV decreases with increasing distance. During tests, the simplified approach with tracing back distance of 1 CTU size gives the best gain vs. complexity trade-off.

According to certain embodiments, the second scheme may also be applied for blocks that already have inter coded neighbors, as it may increase the likelihood of finding the most relevant MV predictor.

Both of the proposed first and second schemes for countering the holes of the MV field have been tested under JEM. During tests, the second scheme performed slightly better and showed an average bitrate reduction of 0.3%.

FIGURE 8 illustrates an example method 100 for improving MV prediction, according to certain embodiments. In a particular embodiment, the method is performed by a transmitter, which may include a wireless device or a network node, according to particular embodiments. In other embodiments, the method may be performed by a receiver, which may include wireless device or a network node, according to particular embodiments. In a particular embodiment, the method may be performed by an encoder. In other embodiments, the method may be performed by a decoder

At step 102, the method 100 includes identifying a hole of a motion vector field inside a picture in a video sequence.

At step 104, the hole of the MV field is countered.

According to certain embodiments implementing the first scheme described herein, the step of countering the hole includes filling the hole when the hole is first introduced. FIGURE 9 illustrates a method for countering the hole when the hole is first introduced. In a particular embodiment, for example, the hole may be filled during or just after encoding or decoding.

The method begins at step 202 when a list of MV candidates for a block of pictures in the video sequence is derived. At 204, a MV candidate is selected from the list. At step 206, the selected MV candidate is stored. In a particular embodiment, the first MV candidate in the list may be selected. In another embodiment, a MV candidate that is closest to an average of all the neighboring candidates may be selected. In still another embodiment, motion compensation may be applied for each MV candidate and the MV candidate that results in a smallest difference between a motion-compensated block and a current block's reconstruction may be selected.

At step 208, the MV candidate is used for prediction in at least one future inter block.

According to certain other embodiments implementing the second scheme described herein, the step of countering the hole may include jumping through the hole when encoding or decoding a future inter block. FIGURE 10 illustrates a method for countering the hole when encoding or decoding a future inter block. At step 302, a search range or the allowed positions for fetching one or more neighboring MVs is increased. In a particular embodiment, this may include tracing previous inter coded blocks in an inverse decoding order, calculating a spatial distance to the current block, and selecting the MV candidate that is closest to the additional candidate for predicting a current MV. In another embodiment, MVs may be prioritized based on a sign that indicate the MVs are better for prediction such as for example where an encountered inter block does not contain any residual information.

In certain embodiments, the method for improving MV prediction, as described above may be performed by a virtual computing device. FIGURE 11 illustrates an example virtual computing device 400 for improving MV prediction, according to certain embodiments. In certain embodiments, virtual computing device 400 may include modules for performing steps similar to those described above with regard to the method illustrated and described in FIGURE 8. For example, virtual computing device 400 may include an identifying module 410, a countering module 420, and any other suitable modules for improving MV prediction. In some embodiments, one or more of the modules may be implemented using processing circuitry 1020 of FIGURE 17 or processing 1120 of FIGURE 18, discussed below. In certain embodiments, the functions of two or more of the various modules may be combined into a single module.

The identifying module 410 may perform the identifying functions of virtual computing device 400. For example, in a particular embodiment, identifying module 410 may identify a hole of a motion vector field inside a picture in a video sequence.

The countering module 420 may perform the countering functions of virtual computing device 400. For example, in a particular embodiment, countering module 420 may counter the hole of the MV field.

Other embodiments of virtual computing device 400 may include additional components beyond those shown in FIGURE 11 that may be responsible for providing certain aspects of the functionality, including any of the functionality described above and/or any additional functionality (including any functionality necessary to support the solutions described above). The various different types of radio nodes for performing the functionality may include components having the same physical hardware but configured (e.g., via programming) to support different radio access technologies, or may represent partly or entirely different physical components.

FIGURE 12 illustrates another method for improved MV prediction, according to certain embodiments. In a particular embodiment, the method is performed by an encoder. In another embodiment, the method is performed by a decoder.

The method begins at step 510 when a hole of a MV field is identified inside an inter picture in a video sequence. The hole of the MV field comprises a block in a current picture that does not contain a MV for at least one reference picture of the inter picture.

In a particular embodiment, the block in the video sequence is an intra block. For example, an inter B picture allows a block to have two MVs pointing to two reference pictures. However, an intra block does not contain any MV for any reference picture

In another embodiment, the block is a uni-predicted inter block inside the video sequence. As described above, a uni-predicted inter block only contains a MV for one reference picture. The uni-predicted inter block does not contain a MV for the other reference picture.

At step 520, a list of a plurality of MV candidates is derived for the block in the video sequence. A particular MV candidate is selected from the list of the plurality of MV candidates, at step 530.

In a particular embodiment, the method may further include storing the particular MV candidate and using the particular MV candidate for prediction in at least one additional block within the video sequence.

In a particular embodiment, the particular MV candidate may be the particular MV candidate that is listed first in the list of the plurality of MV candidates.

In another embodiment, the particular MV candidate may be the particular MV candidate that is closest to an average of the plurality of MV candidates, where each of the plurality of MV candidates is associated with one of a plurality of neighboring blocks that are adjacent to the block.

In still another embodiment, selecting the particular MV candidate may include applying motion compensation for each of the plurality of MV candidates and selecting the particular MV candidate that results in a smallest difference between a motion-compensated block and a reconstruction of the current block. For example, motion compensation is a process where an encoder or decoder uses MV to fetch a corresponding block from the reference picture that the MV points to. When applying motion compensation for each MV, a motion compensated block is generated. The particular MV candidate with the smallest difference between the motion-compensated block and the reconstruction of the current block is referring to the accumulated pixel value differences between the two.

In a particular embodiment, only the pixels that are adjacent to the right boundary and the bottom boundary of the block are used in determining the particular MV candidate with the smallest difference between the motion compensated block and the current block. Additionally or alternatively, at least one pixel that is adjacent to the right boundary or the bottom boundary of the block is assigned a higher weight than at least one pixel that is not adjacent to the right boundary or the bottom boundary.

In yet another particular embodiment, the method may further include, for an uni-predicted inter block, scaling the MV of the block to another direction and selecting the particular MV candidate from the list of the plurality of MV candidates that differs a most from the MV after scaling. For example, the accumulated absolute difference between corresponding components of two MVs, MV0 and MV1, may be calculated to measure the difference between the two MVs as follows:

$$\text{Diff} = \text{Abs}(Mv0\_x - Mv1\_x) + \text{Abs}(Mv0\_x - Mv1\_y)$$

As another example, according to certain embodiments, a MV contains two components, x and y, which signal horizontal displacement and vertical displacement, respectively. When scaling a MV, three values are needed. First, the current picture's picture order count (POCA) is needed. Second, a first reference picture's picture order count (POC0) is needed. Finally, a second reference picture's picture order count (POC1) is needed. For an uni-predicted block, assuming its MV pointing to the first reference picture, the MV (MV_new) to the second reference picture should be (denoting the two components for MV_new as MV_new_x and MV_new_y):

$$MV\_new\_x = MV\_x * (POC1 - POCA) / (POC0 - POCA).$$

$$MV\_new\_y = MV\_y * (POC1 - POCA) / (POC0 - POCA).$$

In other words, the two components of a MV are scaled according to the temporal picture distances.

At step 540, the hole of the MV field is filled with the particular MV candidate when the hole is introduced. In a particular embodiment, the hole may be introduced during encoding or decoding of the video sequence.

In a particular embodiment, filling in the hole of the MV field may include deriving a list of a plurality of MV candidates for the block in the video sequence and selecting a MV candidate from the list of the plurality of MV candidates. The selected the MV candidate may be stored and used for prediction in at least one additional block within the video sequence.

In certain embodiments, the method for improving MV prediction, as described above may be performed by a virtual computing device. FIGURE 13 illustrates an example virtual computing device 600 for improving MV prediction, according to certain embodiments. In certain embodiments, virtual computing device 600 may include modules for performing steps similar to those described above with regard to the method illustrated and described in FIGURE 12. For example, virtual computing device 600 may include an identifying module 610, a deriving module 620, a selecting module 630, a filling module 640, and any other suitable modules for improving MV prediction. In some embodiments, one or more of the modules may be implemented using processing circuitry 1020 of FIGURE 17 or processing 1120 of FIGURE 18, discussed below. In certain embodiments, the functions of two or more of the various modules may be combined into a single module.

The identifying module 610 may perform the identifying functions of virtual computing device 600. For example, in a particular embodiment, identifying module 610 may identify a hole of a MV field inside an inter picture in a video sequence. The hole of the MV field comprises a block in a current picture that does not contain a MV for at least one reference picture of the inter picture.

The deriving module 620 may perform the deriving functions of virtual computing device 600. For example, in a particular embodiment, deriving module 620 may derive a list of a plurality of MV candidates for the block in the sequence.

The selecting module 630 may perform the selecting functions of virtual computing device 600. For example, in a particular embodiment, selecting module 630 may select a particular MV candidate from the list of the plurality of MV candidates.

The filling module 640 may perform the filling functions of virtual computing device 600. For example, in a particular embodiment, filling module 640 may fill the hole of the MV field with the particular MV candidate when the hole is introduced

Other embodiments of virtual computing device 600 may include additional components beyond those shown in FIGURE 13 that may be responsible for providing certain aspects of the functionality, including any of the functionality described above and/or any additional functionality (including any functionality necessary to support the solutions described above). The various different types of radio nodes for performing the functionality may include components having the same physical hardware but configured (e.g., via programming) to support different radio access technologies, or may represent partly or entirely different physical components.

FIGURE 14 illustrates another method for improved MV prediction, according to certain embodiments. In a particular embodiment, the method is performed by an encoder. In a particular embodiment, the method is performed by a decoder.

The method begins at step 710 when a hole of a MV field in an inter picture of a video sequence is identified when encoding or decoding a current block of the inter picture. The hole of the MV field includes a previously encoded or decoded block in the inter picture that does not contain a MV.

At step 720, the hole of the MV field is countered by increasing a search range for fetching at least one neighboring MV used to predict a candidate MV for the previously encoded or decoded block.

In a particular embodiment, countering the hole of the MV field includes tracing a plurality of previously encoded or decoded blocks in an inverse decoding order. For each of the plurality of previously encoded or decoded blocks, a spatial distance to the current block is calculated. The MV candidate is selected that is associated with a particular one of the plurality of previously encoded or decoded blocks that is closest to the current block. The particular block that is closest to the current block may be the block that has a lowest calculated spatial distance from the current block, in a particular embodiment.

In a particular embodiment, a threshold on a distance of tracing back is imposed when tracing the plurality of previously encoded or decoded blocks.

In a particular embodiment, the inverse decoding order for tracing the plurality of previously encoded or decoded blocks is: a left neighboring block relative to the current block, a top neighboring block relative to the current block, a top-right neighboring block relative to the current block, a left-bottom neighboring block relative to the current block, and a top-left neighboring block relative to the current block.

In a particular embodiment, the at least one neighboring MV used to predict the candidate MV is associated with a block of the video sequence that is not adjacent to the current block.

In a particular embodiment, the block that is not adjacent to the current block is adjacent to one of: a left neighboring block relative to the current block, a top neighboring block relative to the current block, a top-right neighboring block to the current block, a left-bottom neighboring block to the current block, or a top-left neighboring block to the current block.

In a particular embodiment, countering the hole of the MV field comprises prioritizing a MV having a sign that indicates that the previously encoded or decoded block does not contain any residual information.

In a particular embodiment, the method further includes, for each of the at least one neighboring MVs, measuring a straight horizontal spatial distance or straight vertical spatial distance relative to the current block. The candidate MV may be selected from the at least one neighboring MVs that have a straight horizontal spatial distance or a straight vertical spatial distance less than a threshold.

In certain embodiments, the method for improving MV prediction, as described above may be performed by a virtual computing device. FIGURE 15 illustrates another example virtual computing device 800 for improving MV prediction, according to certain embodiments. In certain embodiments, virtual computing device 800 may include modules for performing steps similar to those described above with regard to the method illustrated and described in FIGURE 14. For example, virtual computing device 800 may include an identifying module 810, a countering module 820, and any other suitable modules for improving MV prediction. In some embodiments, one or more of the modules may be implemented using processing circuitry 1020 of FIGURE 17 or processing 1120 of FIGURE 18, discussed below. In certain embodiments, the functions of two or more of the various modules may be combined into a single module.

The identifying module 810 may perform the identifying functions of virtual computing device 800. For example, in a particular embodiment, when encoding or decoding a current block inside an inter picture of a video sequence, identifying module 810 may identify a hole of a MV field in the inter picture. The hole of the MV field includes a previously encoded or decoded block in the inter picture that does not contain a MV.

The countering module 820 may perform the countering functions of virtual computing device 800. For example, in a particular embodiment, countering module 820 may counter the hole of the MV field by increasing a search range for fetching at least one neighboring MV used to predict a candidate MV for the previously encoded or decoded block.

Other embodiments of virtual computing device 800 may include additional components beyond those shown in FIGURE 14 that may be responsible for providing certain aspects of the functionality, including any of the functionality described above and/or any additional functionality (including any functionality necessary to support the solutions described above). The various different types of radio nodes for performing the functionality may include components having the same physical hardware but configured (e.g., via programming) to support different radio access technologies, or may represent partly or entirely different physical components.

FIGURE 16 is a block diagram illustrating an embodiment of a network 900 for improving MV prediction, in accordance with certain embodiments. Network 900 includes one or more wireless devices 910A-C, which may be interchangeably referred to as wireless devices 910 or UEs 910, and network nodes 915A-C, which may be interchangeably referred to as network nodes 915 or eNodeBs 915, radio network controller 920, and a core network node 930. A wireless device 910 may communicate with network nodes 915 over a wireless interface. For example, wireless device 910A may transmit wireless signals to one or more of network nodes 915, and/or receive wireless signals from one or more of network nodes 915. The wireless signals may contain voice traffic, data traffic, control signals, and/or any other suitable information. In some embodiments, an area of wireless signal coverage associated with a network node 915 may be referred to as a cell. In some embodiments, wireless devices 910 may have D2D capability. Thus, wireless devices 910 may be able to receive signals from and/or transmit signals directly to another wireless device 910. For example, wireless device 910A may be able to receive signals from and/or transmit signals to wireless device 910B.

In certain embodiments, network nodes 915 may interface with a radio network controller 920. Radio network controller 920 may control network nodes 915 and may provide certain radio resource management functions, mobility management functions, and/or other suitable functions. In certain embodiments, radio network controller 920 may interface with core network node 930 via an interconnecting network. The interconnecting network may refer to any interconnecting system capable of transmitting audio, video, signals, data, messages, or any combination of the preceding. The interconnecting network may include all or a portion of a public switched telephone network (PSTN), a public or private data network, a local area network (LAN), a metropolitan area network (MAN), a wide area network (WAN), a local, regional, or global communication or computer network such as the Internet, a wireline or wireless network, an enterprise intranet, or any other suitable communication link, including combinations thereof.

Core network node 930 may manage the establishment of communication sessions and provide various other functionality for wireless communication device 910. Wireless communication device 910 exchanges certain signals with core network node 930 using the non-access stratum layer. In non-access stratum (NAS) signaling, signals between wireless communication device 910 and core network node 930 pass transparently through network nodes 920.

As described above, example embodiments of network 900 may include one or more wireless devices 910, and one or more different types of network nodes capable of communicating (directly or indirectly) with wireless devices 910. Wireless device 910 may refer to any type of wireless device communicating with a node and/or with another wireless device in a cellular or mobile communication system. Examples of wireless device 910 include a mobile phone, a smart phone, a PDA (Personal Digital Assistant), a portable computer (e.g., laptop, tablet), a sensor, a modem, a machine-type-communication (MTC) device / machine-to-machine (M2M) device, laptop embedded equipment (LEE), laptop mounted equipment (LME), USB dongles, a D2D capable device, or another device that can provide wireless communication. A wireless device 910 may also be referred to as UE, a station (STA), a device, or a terminal in some embodiments. Also, in some embodiments, generic terminology, "radio network node" (or simply "network node") is used. It can be any kind of network node, which may comprise a Node B, base station (BS), multi-standard radio (MSR) radio node such as MSR BS, eNode B, network controller, radio network controller (RNC), base station controller (BSC), relay donor node controlling relay, base transceiver station (BTS), access point (AP), transmission points, transmission nodes, RRU, RRH, nodes in distributed antenna system (DAS), core network node (e.g. MSC, MME etc.), O&M, OSS, SON, positioning node (e.g. E-SMLC), MDT, or any suitable network node. Each of wireless communication device 910, network node 915, radio network controller 920, and core network node 930 include any suitable combination of hardware and/or software. Example embodiments of network nodes 915, wireless devices 910, and other network nodes (such as radio network controller or core network node) are described in more detail with respect to FIGURES 13, 14, and 15, respectively.

Although FIGURE 16 illustrates a particular arrangement of network 900, the present disclosure contemplates that the various embodiments described herein may be applied to a variety of networks having any suitable configuration. For example, network 900 may include any suitable number of wireless devices 910 and network nodes 915, as well as any additional elements suitable to support communication between wireless devices or between a wireless device and another communication device (such as a landline telephone). In certain embodiments, wireless communication device 910, network node 920, and core network node 930 use any suitable radio access technology, such as long term evolution (LTE), LTE-Advanced, UMTS, HSPA, GSM, cdma2000, WiMax, WiFi, another suitable radio access technology, or any suitable combination of one or more radio access technologies. For purposes of example, various embodiments may be described within the context of certain radio access technologies. However, the scope of the disclosure is not limited to the examples and other embodiments could use different radio access technologies.

FIGURE 17 a block schematic of an exemplary wireless device 910 for improving MV prediction, in accordance with certain embodiments. Wireless device 910 may refer to any type of wireless device communicating with a node and/or with another wireless device in a cellular or mobile communication system. Examples of wireless device 910 include a mobile phone, a smart phone, a PDA (Personal Digital Assistant), a portable computer (e.g., laptop, tablet), a sensor, a modem, an MTC device / machine-to-machine (M2M) device, laptop embedded equipment (LEE), laptop mounted equipment (LME), USB dongles, a D2D capable device, or another device that can provide wireless communication. A wireless device 910 may also be referred to as UE, a station (STA), a device, or a terminal in some embodiments. Wireless device 910 includes transceiver 1010, processing circuitry 1020, and memory 1030. In some embodiments, transceiver 1010 facilitates transmitting wireless signals to and receiving wireless signals from network node 915 (e.g., via antenna 1040), processing circuitry 1020 (e.g., which may include one or more processors) executes instructions to provide some or all of the functionality described above as being provided by wireless device 910, and memory 1030 stores the instructions executed by processing circuitry 1020.

Processing circuitry 1020 may include any suitable combination of hardware and software implemented in one or more modules to execute instructions and manipulate data to perform some or all of the described functions of wireless device 910, such as the functions of UE 910 (i.e., wireless device 910) described herein. For example, in general, processing circuitry may identify and counter a hole of a motion vector field inside a picture in a video sequence, as described herein. In some embodiments, processing circuitry 1020 may include, for example, one or more computers, one or more central processing units (CPUs), one or more microprocessors, one or more applications, one or more application specific integrated circuits (ASICs), one or more field programmable gate arrays (FPGAs) and/or other logic.

Memory 1030 is generally operable to store instructions, such as a computer program, software, an application including one or more of logic, rules, algorithms, code, tables, etc. and/or other instructions capable of being executed by a processor. Examples of memory 1030 include computer memory (for example, Random Access Memory (RAM) or Read Only Memory (ROM)), mass storage media (for example, a hard disk), removable storage media (for example, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or or any other volatile or non-volatile, non-transitory computer-readable and/or computer-executable memory devices that store information, data, and/or instructions that may be used by processor 1020.

Other embodiments of wireless device 910 may optionally include additional components beyond those shown in FIGURE 17 that may be responsible for providing certain aspects of the wireless device’s functionality, including any of the functionality described above and/or any additional functionality (including any functionality necessary to support the solution described above). =-Input devices include mechanisms for entry of data into wireless device 910. For example, input devices may include input mechanisms, such as a microphone, input elements, a display, etc. Output devices may include mechanisms for outputting data in audio, video, and/or hard copy format. For example, output devices may include a speaker, a display, etc.

FIGURE 18 is a block schematic of an exemplary network node 915 for improving MV prediction, in accordance with certain embodiments. Network node 915 may be any type of radio network node or any network node that communicates with a UE and/or with another network node. Examples of network node 915 include an gNB, eNodeB, a node B, a base station, a wireless access point (e.g., a Wi-Fi access point), a low power node, a base transceiver station (BTS), relay, donor node controlling relay, transmission points, transmission nodes, remote RF unit (RRU), remote radio head (RRH), multi-standard radio

(MSR) radio node such as MSR BS, nodes in distributed antenna system (DAS), O&M, OSS, SON, positioning node (e.g., E-SMLC), MDT, or any other suitable network node. Network nodes 915 may be deployed throughout network 900 as a homogenous deployment, heterogeneous deployment, or mixed deployment. A homogeneous deployment may generally describe a deployment made up of the same (or similar) type of network nodes 915 and/or similar coverage and cell sizes and inter-site distances. A heterogeneous deployment may generally describe deployments using a variety of types of network nodes 915 having different cell sizes, transmit powers, capacities, and inter-site distances. For example, a heterogeneous deployment may include a plurality of low-power nodes placed throughout a macro-cell layout. Mixed deployments may include a mix of homogenous portions and heterogeneous portions.

Network node 915 may include one or more of transceiver 1120, processing circuitry 1120 (e.g., which may include one or more processors), memory 1130, and network interface 1140. In some embodiments, transceiver 1120 facilitates transmitting wireless signals to and receiving wireless signals from wireless device 910 (e.g., via antenna 1150), processing circuitry 1120 executes instructions to provide some or all of the functionality described above as being provided by a network node 915, memory 1130 stores the instructions executed by processing circuitry 1120, and network interface 1140 communicates signals to backend network components, such as a gateway, switch, router, Internet, Public Switched Telephone Network (PSTN), core network nodes or radio network controllers, etc.

Processing circuitry 1120 may include any suitable combination of hardware and software implemented in one or more modules to execute instructions and manipulate data to perform some or all of the described functions of network node 915, as described herein. For example, in general, processing circuitry 1120 may cause network node to identify and counter a hole of a motion vector field inside a picture in a video sequence. In some embodiments, processing circuitry 1120 may include, for example, one or more computers, one or more central processing units (CPUs), one or more microprocessors, one or more applications, and/or other logic.

Memory 1130 is generally operable to store instructions, such as a computer program, software, an application including one or more of logic, rules, algorithms, code, tables, etc. and/or other instructions capable of being executed by a processor. Examples of memory 1130 include computer memory (for example, Random Access Memory (RAM) or Read Only

Memory (ROM)), mass storage media (for example, a hard disk), removable storage media (for example, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or or any other volatile or non-volatile, non-transitory computer-readable and/or computer-executable memory devices that store information.

In some embodiments, network interface 1140 is communicatively coupled to processing circuitry 1120 and may refer to any suitable device operable to receive input for network node 915, send output from network node 915, perform suitable processing of the input or output or both, communicate to other devices, or any combination of the preceding. Network interface 1140 may include appropriate hardware (e.g., port, modem, network interface card, etc.) and software, including protocol conversion and data processing capabilities, to communicate through a network.

Other embodiments of network node 915 may include additional components beyond those shown in FIGURE 18 that may be responsible for providing certain aspects of the radio network node's functionality, including any of the functionality described above and/or any additional functionality (including any functionality necessary to support the solutions described above). The various different types of network nodes may include components having the same physical hardware but configured (e.g., via programming) to support different radio access technologies, or may represent partly or entirely different physical components.

FIGURE 19 is a block schematic of an exemplary radio network controller or core network node 800, in accordance with certain embodiments. Examples of network nodes can include a mobile switching center (MSC), a serving GPRS support node (SGSN), a mobility management entity (MME), a radio network controller (RNC), a base station controller (BSC), and so on. The radio network controller or core network node includes processing circuitry 1220 (e.g., which may include one or more processors), memory 1230, and network interface 1240. In some embodiments, processing circuitry 1220 executes instructions to provide some or all of the functionality described above as being provided by the network node, memory 1230 stores the instructions executed by processing circuitry 1220, and network interface 1240 communicates signals to any suitable node, such as a gateway, switch, router, Internet, Public Switched Telephone Network (PSTN), network nodes 915, radio network controllers or core network nodes, etc.

Processing circuitry 1220 may include any suitable combination of hardware and software implemented in one or more modules to execute instructions and manipulate data to perform some or all of the described functions of the radio network controller or core network node. In some embodiments, processing circuitry 1220 may include, for example, one or more computers, one or more central processing units (CPUs), one or more microprocessors, one or more applications, and/or other logic.

Memory 1230 is generally operable to store instructions, such as a computer program, software, an application including one or more of logic, rules, algorithms, code, tables, etc. and/or other instructions capable of being executed by a processor. Examples of memory 1230 include computer memory (for example, Random Access Memory (RAM) or Read Only Memory (ROM)), mass storage media (for example, a hard disk), removable storage media (for example, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or or any other volatile or non-volatile, non-transitory computer-readable and/or computer-executable memory devices that store information.

In some embodiments, network interface 1240 is communicatively coupled to processing circuitry 1220 and may refer to any suitable device operable to receive input for the network node, send output from the network node, perform suitable processing of the input or output or both, communicate to other devices, or any combination of the preceding. Network interface 1240 may include appropriate hardware (e.g., port, modem, network interface card, etc.) and software, including protocol conversion and data processing capabilities, to communicate through a network.

Other embodiments of the network node may include additional components beyond those shown in FIGURE 19 that may be responsible for providing certain aspects of the network node's functionality, including any of the functionality described above and/or any additional functionality (including any functionality necessary to support the solution described above).

EXAMPLE EMBODIMENTS

According to certain embodiments, a method by a transmitter for improved motion vector (MV) prediction comprises

- identifying a hole of a motion vector field inside a picture in a video sequence and
- countering the hole of the MV field

- optionally, countering the hole of the MV field comprises filling in the hole when the hole is introduced
- optionally, the hole is introduced during encoding or decoding;
- optionally, countering the hole of the MV field comprises deriving a list of MV candidates for a block of pictures in the video sequence, selecting a MV candidate from the list, storing the selected MV candidate, and using the MV candidate for prediction in at least one future inter block,
- optionally, selecting the MV candidate comprises selecting a first MV candidate from the list,
- optionally, the MV candidate comprises selecting a MV candidate that is closest to an average of all the neighboring candidates,
- optionally, selecting the MV candidate comprises applying motion compensation for each MV candidate and selecting the MV candidate that results in a smallest difference between a motion-compensated block and a current block's reconstruction,
- optionally, pixels that are close to a right boundary and a bottom boundary of the block may be emphasized in the selection of the MV candidate,
- optionally, only the pixels that are adjacent to the right boundary and the bottom boundary may be used in a comparison of a difference between a motion compensated block and the current block,
- optionally, pixels that are adjacent to the right boundary and the bottom boundary may be assigned a higher weight as compared to pixels that are not adjacent to the right boundary or the bottom boundary,
- optionally, the method further includes, for an uni-predicted inter block, scaling the MV of a current block to another direction and selecting the MV candidate of the MV candidate list that differs the most from the scaled MV,
- optionally, countering the hole of the MV field comprises jumping through the hole when encoding or decoding a future inter block,
- optionally, countering the hole of the MV field comprises increasing a search range or the allowed positions for fetching one or more neighboring MVs,
- optionally, countering the hole of the MV field comprises tracing previous inter coded blocks in an inverse decoding order, for each of the previous inter

coded blocks calculating a spatial distance to the current block, and selecting the MV candidate that is closest to the additional candidate for predicting a current MV,

- optionally, a threshold on a distance of tracing back is imposed,
- optionally, countering the hole of the MV field comprises prioritizing MVs that, based on a sign, may be better to use for prediction,
- optionally, the sign indicates that an encountered inter block does not contain any residual information,
- optionally, countering the hole of the MV field comprises including as MV candidates those that are closet in terms of straight horizontal or straight vertical spatial distance,
- optionally, countering the hole of the MV field comprises using a width or height of a block to jump through several columns or lines for faster fetching,

According to certain embodiments, a transmitter for improved motion vector (MV) prediction comprises a memory storing instructions and processing circuitry operable to execute the instructions to cause the transmitter to perform any of embodiments described above. Optionally, the transmitter comprises at least one of a wireless device, a network node, an encoder, and a decoder.

According to certain embodiments, a non-transitory computer readable medium stores instructions that are executable by a processor to perform any of the example embodiments described above.

According to certain embodiments, a computer program product comprises a non-transitory computer readable medium storing computer readable program code. The computer readable program code comprises program code for performing any of the embodiments described above.

According to certain embodiments, a method by a receiver for improved MV prediction comprises

- identifying a hole of a motion vector field inside a picture in a video sequence, and
- countering the hole of the MV field,
- optionally, the hole of the MV field comprises filling in the hole when the hole

is introduced,

- optionally, the hole is introduced during encoding or decoding,
    - optionally, countering the hole of the MV field comprises deriving a list of MV candidates for a block of pictures in the video sequence, selecting a MV candidate from the list; storing the selected MV candidate; and using the MV candidate for prediction in at least one future inter block,
    - optionally, selecting the MV candidate comprises selecting a first MV candidate from the list,
    - optionally, selecting the MV candidate comprises selecting a MV candidate that is closest to an average of all the neighboring candidates,
    - optionally, selecting the MV candidate comprises applying motion compensation for each MV candidate and selecting the MV candidate that results in a smallest difference between a motion-compensated block and a current block's reconstruction,
    - optionally, pixels that are close to a right boundary and a bottom boundary of the block may be emphasized in the selection of the MV candidate,
    - optionally, only the pixels that are adjacent to the right boundary and the bottom boundary may be used in a comparison of a difference between a motion compensated block and the current block,
    - optionally, pixels that are adjacent to the right boundary and the bottom boundary may be assigned a higher weight as compared to pixels that are not adjacent to the right boundary or the bottom boundary,
    - optionally, for an uni-predicted inter block, the method further includes scaling the MV of a current block to another direction and selecting the MV candidate of the MV candidate list that differs the most from the scaled MV,
    - optionally, countering the hole of the MV field comprises jumping through the hole when encoding or decoding a future inter block,
    - optionally, countering the hole of the MV field comprises increasing a search range or the allowed positions for fetching one or more neighboring MVs,
    - optionally, countering the hole of the MV field comprises tracing

previous inter coded blocks in an inverse decoding order, for each of the previous inter coded blocks calculating a spatial distance to the current block, and selecting the MV candidate that is closest to the additional candidate for predicting a current MV,

- optionally, a threshold on a distance of tracing back is imposed,
- optionally, countering the hole of the MV field comprises prioritizing MVs that, based on a sign, may be better to use for prediction,
- optionally, the sign indicates that an encountered inter block does not contain any residual information,
- optionally, countering the hole of the MV field comprises including as MV candidates those that are closet in terms of straight horizontal or straight vertical spatial distance,
- optionally, countering the hole of the MV field comprises using a width or height of a block to jump through several columns or lines for faster fetching.

According to certain embodiments, a receiver for improved MV prediction comprises a memory storing instructions and processing circuitry operable to execute the instructions to cause the receiver to perform any of embodiments described above. Optionally, the receiver comprises at least one of a wireless device, a network node, an encoder, and a decoder.

According to certain embodiments, a non-transitory computer readable medium stores instructions that are executable by a processor to perform any of the example embodiments described above.

According to certain embodiments, a computer program product comprises a non-transitory computer readable medium storing computer readable program code. The computer readable program code comprises program code for performing any of the methods of example embodiments described above.

Modifications, additions, or omissions may be made to the systems and apparatuses described herein without departing from the scope of the disclosure. The components of the systems and apparatuses may be integrated or separated. Moreover, the operations of the systems and apparatuses may be performed by more, fewer, or other components. Additionally, operations of the systems and apparatuses may be performed using any suitable logic comprising software, hardware, and/or other logic. As used in this document, “each” refers to each member of a set or each member of a subset of a set.

Modifications, additions, or omissions may be made to the methods described herein without departing from the scope of the disclosure. The methods may include more, fewer, or other steps. Additionally, steps may be performed in any suitable order.

Although this disclosure has been described in terms of certain embodiments, alterations and permutations of the embodiments will be apparent to those skilled in the art. Accordingly, the above description of the embodiments does not constrain this disclosure. Other changes, substitutions, and alterations are possible without departing from the spirit and scope of this disclosure.

ABBREVIATIONS

Abbreviation	Explanation
1x RTT	CDMA2000 1x Radio Transmission Technology
3GPP	3rd Generation Partnership Project
5G	5th Generation
ABS	Almost Blank Subframe
ARQ	Automatic Repeat Request
AWGN	Additive White Gaussian Noise
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
CA	Carrier Aggregation
CC	Carrier Component
CCCH SDU	Common Control Channel SDU
CDMA	Code Division Multiplexing Access
CGI	Cell Global Identifier
CIR	Channel Impulse Response
CP	Cyclic Prefix

CPICH	Common Pilot Channel
CPICH Ec/No	CPICH Received energy per chip divided by the power density in the band
CQI	Channel Quality information
C-RNTI	Cell RNTI
CSI	Channel State Information
DCCH	Dedicated Control Channel
DL	Downlink
DM	Demodulation
DMRS	Demodulation Reference Signal
DRX	Discontinuous Reception
DTX	Discontinuous Transmission
DTCH	Dedicated Traffic Channel
DUT	Device Under Test
E-CID	Enhanced Cell-ID (positioning method)
E-SMLC	Evolved-Serving Mobile Location Centre
ECGI	Evolved CGI
eNB	E-UTRAN NodeB
ePDCCH	enhanced Physical Downlink Control Channel
E-SMLC	evolved Serving Mobile Location Center
E-UTRA	Evolved UTRA
E-UTRAN	Evolved UTRAN
FDD	Frequency Division Duplex
FFS	For Further Study
GERAN	GSM EDGE Radio Access Network

gNB	Base station in NR
GNSS	Global Navigation Satellite System
GSM	Global System for Mobile communication
HARQ	Hybrid Automatic Repeat Request
HO	Handover
HSPA	High Speed Packet Access
HRPD	High Rate Packet Data
LOS	Line of Sight
LPP	LTE Positioning Protocol
LTE	Long-Term Evolution
MAC	Medium Access Control
MBMS	Multimedia Broadcast Multicast Services
MBSFN	Multimedia Broadcast multicast service Single Frequency Network
MBSFN ABS	MBSFN Almost Blank Subframe
MDT	Minimization of Drive Tests
MIB	Master Information Block
MME	Mobility Management Entity
MSC	Mobile Switching Center
NPDCCH	Narrowband Physical Downlink Control Channel
NR	New Radio
OCNG	OFDMA Channel Noise Generator
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OSS	Operations Support System

OTDOA	Observed Time Difference of Arrival
O&M	Operation and Maintenance
PBCH	Physical Broadcast Channel
P-CCPCH	Primary Common Control Physical Channel
PCell	Primary Cell
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDP	Profile Delay Profile
PDSCH	Physical Downlink Shared Channel
PGW	Packet Gateway
PHICH	Physical Hybrid-ARQ Indicator Channel
PLMN	Public Land Mobile Network
PMI	Precoder Matrix Indicator
PRACH	Physical Random Access Channel
PRS	Positioning Reference Signal
PSS	Primary Synchronization Signal
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
RACH	Random Access Channel
QAM	Quadrature Amplitude Modulation
RAN	Radio Access Network
RAT	Radio Access Technology
RLM	Radio Link Management
RNC	Radio Network Controller
RNTI	Radio Network Temporary Identifier

RRC	Radio Resource Control
RRM	Radio Resource Management
RS	Reference Signal
RSCP	Received Signal Code Power
RSRP	Reference Symbol Received Power OR Reference Signal Received Power
RSRQ	Reference Signal Received Quality OR Reference Symbol Received Quality
RSSI	Received Signal Strength Indicator
RSTD	Reference Signal Time Difference
SCH	Synchronization Channel
SCell	Secondary Cell
SDU	Service Data Unit
SFN	System Frame Number
SGW	Serving Gateway
SI	System Information
SIB	System Information Block
SNR	Signal to Noise Ratio
SON	Self Optimized Network
SS	Synchronization Signal
SSS	Secondary Synchronization Signal
TDD	Time Division Duplex
TDOA	Time Difference of Arrival
TOA	Time of Arrival
TSS	Tertiary Synchronization Signal
TTI	Transmission Time Interval

UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunication System
USIM	Universal Subscriber Identity Module
UTDOA	Uplink Time Difference of Arrival
UTRA	Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Radio Access Network
WCDMA	Wide CDMA
WLAN	Wide Local Area Network

CLAIMS

1. A method for improved motion vector (MV) prediction comprises:

identifying a hole of a MV field inside an inter picture in a video sequence, the hole of the MV field comprising a block in a current picture that does not contain a MV for at least one reference picture of the inter picture;

deriving a list of a plurality of MV candidates for the block in the video sequence;

selecting a particular MV candidate from the list of the plurality of MV candidates; and

filling in the hole of the MV field with the particular MV candidate when the hole is introduced.

2. The method of Claim 1, wherein the block in the video sequence is an intra block.

3. The method of Claim 1, wherein the block is a uni-predicted inter block inside the video sequence.

4. The method of any one of Claims 1 to 3, wherein the hole is introduced during encoding or decoding of the video sequence.

5. The method of any of Claims 1 to 4, wherein filling in the hole of the MV field comprises:

storing the particular MV candidate selected from the list of the plurality of MV candidates; and

using the MV candidate for prediction in at least one additional block within the video sequence.

6. The method of any one of Claims 1 to 5, wherein selecting the particular MV candidate comprises selecting the particular MV candidate that is listed first in the list of the plurality of MV candidates.

7. The method of any one of Claims 1 to 5, wherein selecting the particular MV candidate

comprises selecting the particular MV candidate that is closest to an average of the plurality of MV candidates, wherein each of the plurality of MV candidates is associated with one of a plurality of neighboring blocks that are adjacent to the block.

8. The method of any one of Claims 1 to 5, wherein selecting the particular MV candidate comprises:

applying motion compensation for each of the plurality of MV candidates; and

selecting the particular MV candidate that results in a smallest difference between a motion-compensated block and a reconstruction of the current block.

9. The method of Claim 8, wherein only the pixels that are adjacent to the right boundary and the bottom boundary of the block are used in determining the particular MV candidate with the smallest difference between the motion compensated block and the current block.

10. The method of Claim 8, wherein at least one pixel that is adjacent to the right boundary or the bottom boundary of the block is assigned a higher weight than at least one pixel that is not adjacent to the right boundary or the bottom boundary.

11. The method of any one of Claims 1 to 5, further comprising:

for an uni-predicted inter block, scaling the MV of the block to another direction; and

selecting the particular MV candidate from the list of the plurality of MV candidates that differs a most from the MV after scaling.

12. The method of any one of Claims 1 to 11, wherein the method is performed by an encoder.

13. The method of any one of Claims 1 to 11, wherein the method is performed by a decoder.

14. A non-transitory computer readable medium storing instructions that are executable by a processor to perform any of the example Claims 1 to 13.

15. A computer program product comprising a non-transitory computer readable medium storing computer readable program code, the computer readable program code comprises program code for performing any of the methods of example Claims 1 to 13.

16. A device for improved motion vector (MV) prediction comprising:

a memory storing instructions; and

processing circuitry operable to execute the instructions to cause the device to:

identify a hole of a MV field inside an inter picture in a video sequence, the hole of the MV field comprising a block in a current picture that does not contain a MV for at least one reference picture of the inter picture;

derive a list of a plurality of MV candidates for the block in the video sequence;

select a particular MV candidate from the list of the plurality of MV candidates; and

fill in the hole of the MV field with the particular MV candidate when the hole is introduced.

17. The device of Claim 16, wherein the block in the video sequence is an intra block.

18. The device of Claim 16, wherein the block is a uni-predicted inter block inside the video sequence.

19. The device of any one of Claims 16 to 18, wherein the hole is introduced during encoding or decoding of the video sequence.

20. The device of any of Claims 16 to 19, wherein when filling in the hole of the MV field the processing circuitry is operable to execute the instructions to cause the device to:

store the particular MV candidate selected from the list of the plurality of MV candidates; and

use the particular MV candidate for prediction in at least one additional block within the video sequence.

21. The device of any one of Claims 16 to 20, wherein when selecting the particular MV

candidate the processing circuity is operable to execute the instructions to cause the device to select the particular MV candidate that is listed first in the list of the plurality of MV candidates.

22. The device of any one of Claims 16 to 20, wherein when selecting the particular MV candidate the processing circuity is operable to execute the instructions to cause the device to select the particular MV candidate that is closest to an average of the plurality of MV candidates, wherein each of the plurality of MV candidates is associated with one of a plurality of neighboring blocks that are adjacent to the block.

23. The device of any one of Claims 16 to 20, wherein when selecting the particular MV candidate the processing circuity is operable to execute the instructions to cause the device to:

apply motion compensation for each of the plurality of MV candidates; and

select the particular MV candidate that results in a smallest difference between a motion-compensated block and a reconstruction of the current block.

24. The device of Claim 23, wherein only the pixels that are adjacent to the right boundary and the bottom boundary of the block are used in determining the particular MV candidate with the smallest difference between the motion compensated block and the current block.

25. The device of Claim 23, wherein at least one pixel that is adjacent to the right boundary or the bottom boundary of the block is assigned a higher weight than at least one pixel that is not adjacent to the right boundary or the bottom boundary.

26. The device of any one of Claims 16 to 20, wherein the processing circuitry is operable to execute the instructions to cause the device to:

for an uni-predicted inter block, scale the MV of the block to another direction; and

select the particular MV candidate from the list of the plurality of MV candidates that differs a most from the MV after scaling.

27. The device of any one of Claims 16 to 26, wherein the device an encoder.

28. The device of any one of Claims 16 to 26, wherein the device is a decoder.

29. A method for improved motion vector (MV) prediction comprises:

when encoding or decoding a current block inside an inter picture of a video sequence, identifying a hole of a MV field in the inter picture, the hole of the MV field comprising a previously encoded or decoded block in the inter picture that does not contain a MV for at least one reference picture of the inter picture; and

countering the hole of the MV field by increasing a search range for fetching at least one neighboring MV used to predict a candidate MV for the previously encoded or decoded block.

30. The method of Claim 29, wherein countering the hole of the MV field comprises:

tracing a plurality of previously encoded or decoded blocks in an inverse decoding order;

for each of the plurality of previously encoded or decoded blocks, calculating a spatial distance to the current block; and

select the MV candidate that is associated with a particular one of the plurality of previously encoded or decoded blocks that is closest to the current block.

31 The method of Claim 30, wherein a threshold on a distance of tracing back is imposed when tracing the plurality of previously encoded or decoded blocks.

32. The method of any one of Claims 30 to 31, wherein the inverse decoding order for tracing the plurality of previously encoded or decoded blocks is:

a left neighboring block relative to the current block,

a top neighboring block relative to the current block,

a top-right neighboring block relative to the current block,

a left-bottom neighboring block relative to the current block, and

a top-left neighboring block relative to the current block.

33. The method of any one of Claims 29 to 32, wherein the at least one neighboring MV

used to predict the candidate MV is associated with a block of the video sequence that is not adjacent to the current block.

34. The method of Claim 33, wherein the block that is not adjacent to the current block is adjacent to one of:

a left neighboring block relative to the current block ,
a top neighboring block relative to the current block,
a top-right neighboring block to the current block,
a left-bottom neighboring block to the current block, or
a top-left neighboring block to the current block.

35. The method of any one of Claims 29 to 34, wherein countering the hole of the MV field comprises prioritizing a MV having a sign that indicates that the previously encoded or decoded block does not contain any residual information.

36. The method of any one of Claims 29 to 35, further comprising:

for each of the at least one neighboring MVs, measuring a straight horizontal spatial distance or straight vertical spatial distance relative to the current block; and

selecting the candidate MV from the at least one neighboring MVs that have a straight horizontal spatial distance or a straight vertical spatial distance less than a threshold.

37. The method of any one of Claims 29 to 36, wherein the method is performed by an encoder.

38. The method of any one of Claims 29 to 36, wherein the method is performed by a decoder.

39. A non-transitory computer readable medium storing instructions that are executable by a processor to perform any of Claims 29 to 38.

40. A computer program product comprising a non-transitory computer readable medium storing computer readable program code, the computer readable program code comprises

program code for performing any of the methods of Claims 29 to 38.

41. A device for improved motion vector (MV) prediction comprising:

a memory storing instructions; and

processing circuitry operable to execute the instructions to cause the device to:

when encoding or decoding a current block inside an inter picture of a video sequence, identify a hole of a MV field in the inter picture, the hole of the MV field comprising a previously encoded or decoded block in the inter picture that does not contain a MV for at least one reference picture of the inter picture; and

counter the hole of the MV field by increasing a search range for fetching at least one neighboring MV used to predict a candidate MV for the previously encoded or decoded block.

42. The device of Claim 41, wherein countering the hole of the MV field comprises:

tracing a plurality of previously encoded or decoded blocks in an inverse decoding order;

for each of the plurality of previously encoded or decoded blocks, calculating a spatial distance to the current block; and

select the MV candidate that is associated with a particular one of the plurality of previously encoded or decoded blocks that is closest to the current block.

43. The device of Claim 42, wherein a threshold on a distance of tracing back is imposed when tracing the plurality of previously encoded or decoded blocks.

44. The device of any one of Claims 42 to 43, wherein the inverse decoding order for tracing the plurality of previously encoded or decoded blocks is:

a left neighboring block relative to the current block,

a top neighboring block relative to the current block,

a top-right neighboring block relative to the current block,

a left-bottom neighboring block relative to the current block, and

a top-left neighboring block relative to the current block.

45. The device of any one of Claims 41 to 44, wherein the at least one neighboring MV used to predict the candidate MV is associated with a block of the video sequence that is not adjacent to the current block.

46. The device of Claim 45, wherein the block that is not adjacent to the current block is adjacent to one of:

a left neighboring block relative to the current block,

a top neighboring block relative to the current block,

a top-right neighboring block to the current block,

a left-bottom neighboring block to the current block, or

a top-left neighboring block to the current block.

47. The device of any one of Claims 41 to 46, wherein when countering the hole of the MV field the processing circuitry is operable to execute the instructions to cause the device to prioritize a MV having a sign that indicates that the previously encoded or decoded block does not contain any residual information.

48. The device of any one of Claims 41 to 47, wherein the processing circuitry is operable to execute the instructions to cause the device to:

for each of the at least one neighboring MVs, measuring a straight horizontal spatial distance or straight vertical spatial distance relative to the current block; and

selecting the candidate MV from the at least one neighboring MVs that have a straight horizontal spatial distance or a straight vertical spatial distance less than a threshold.

49. The device of any one of Claims 41 to 48, wherein the device is an encoder.

50. The device of any one of Claims 41 to 48, wherein the device is a decoder.

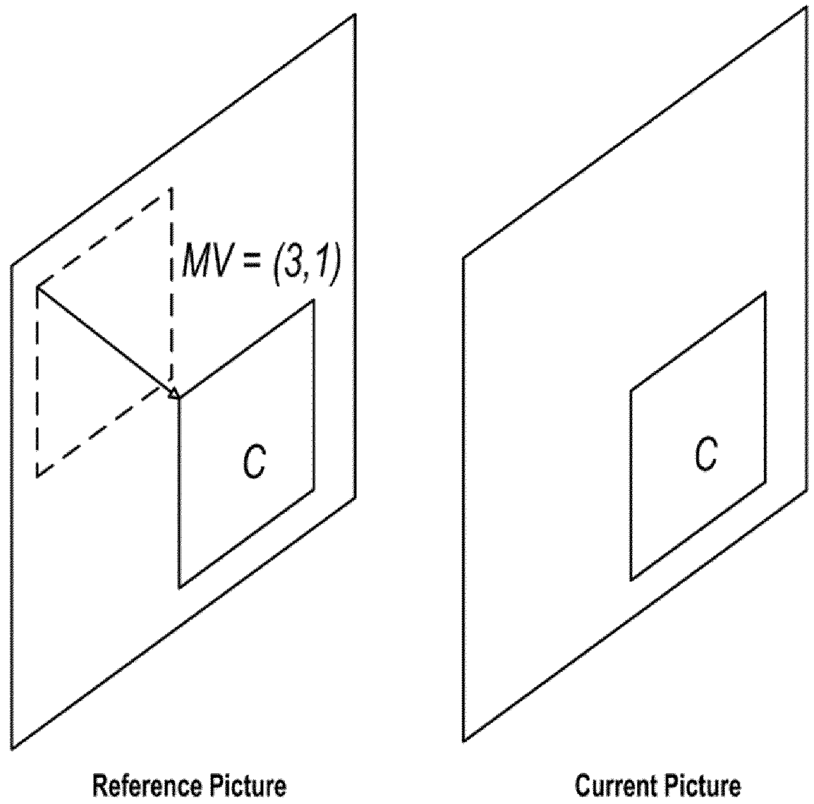

FIGURE 1

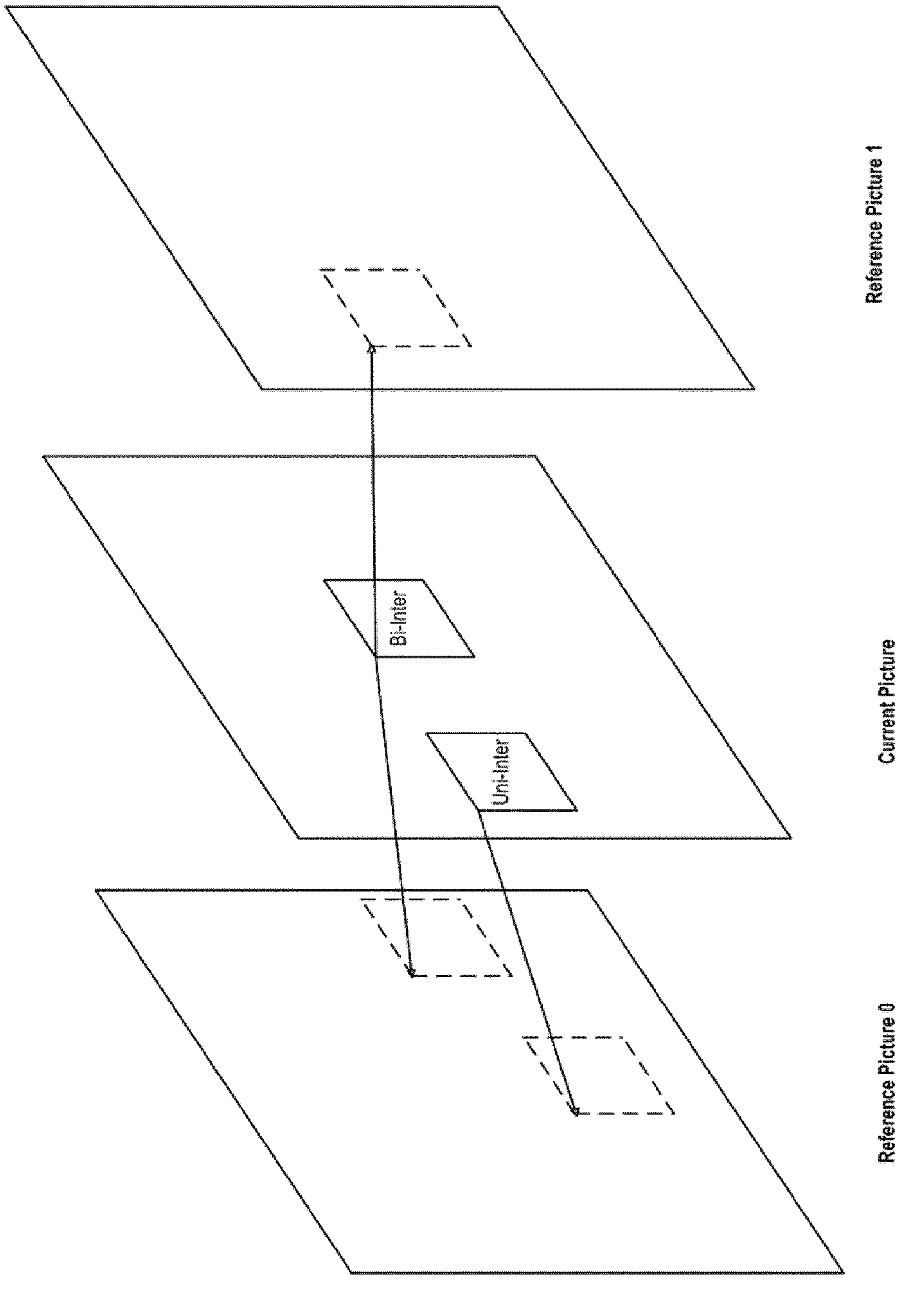
Reference Picture 1
Bi-Inter
Uni-Inter
Current Picture
Reference Picture 0

FIGURE 2

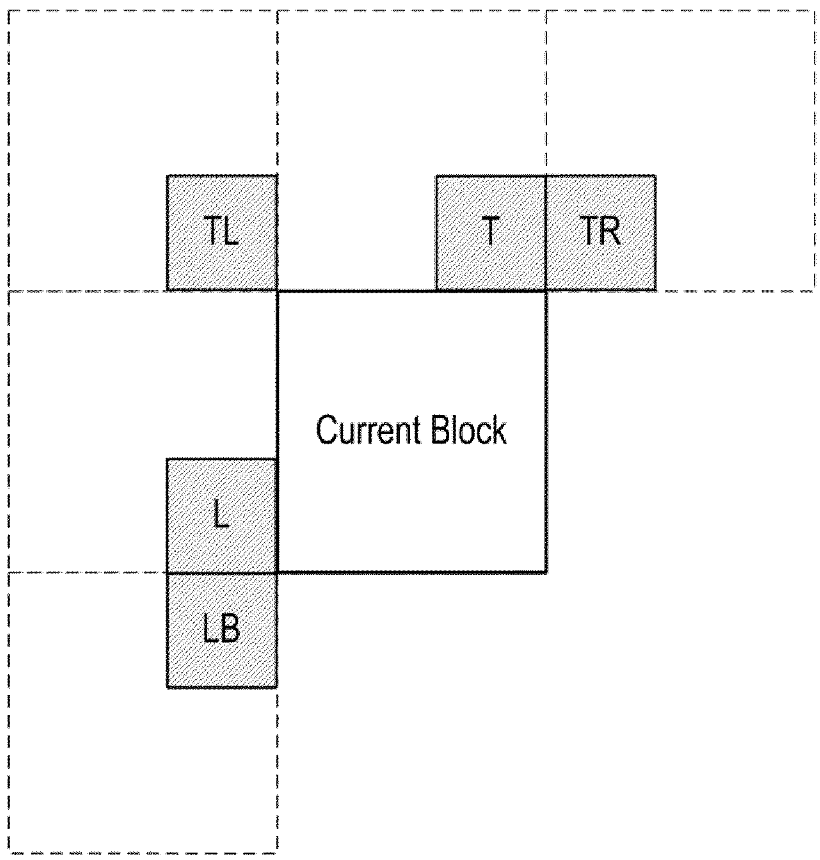

FIGURE 3

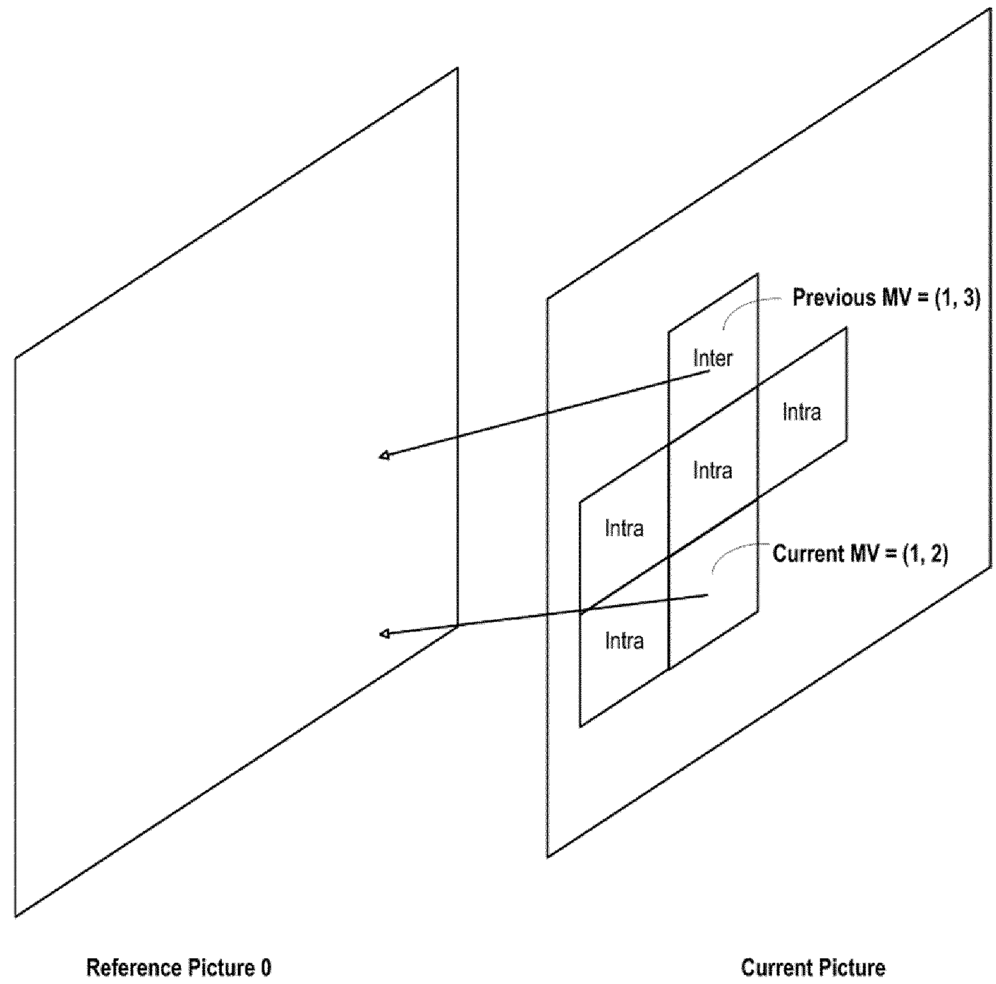
Previous MV = (1, 3)
Inter
Intra
Intra
Intra
Current MV = (1, 2)
Intra
Reference Picture 0
Current Picture

FIGURE 4

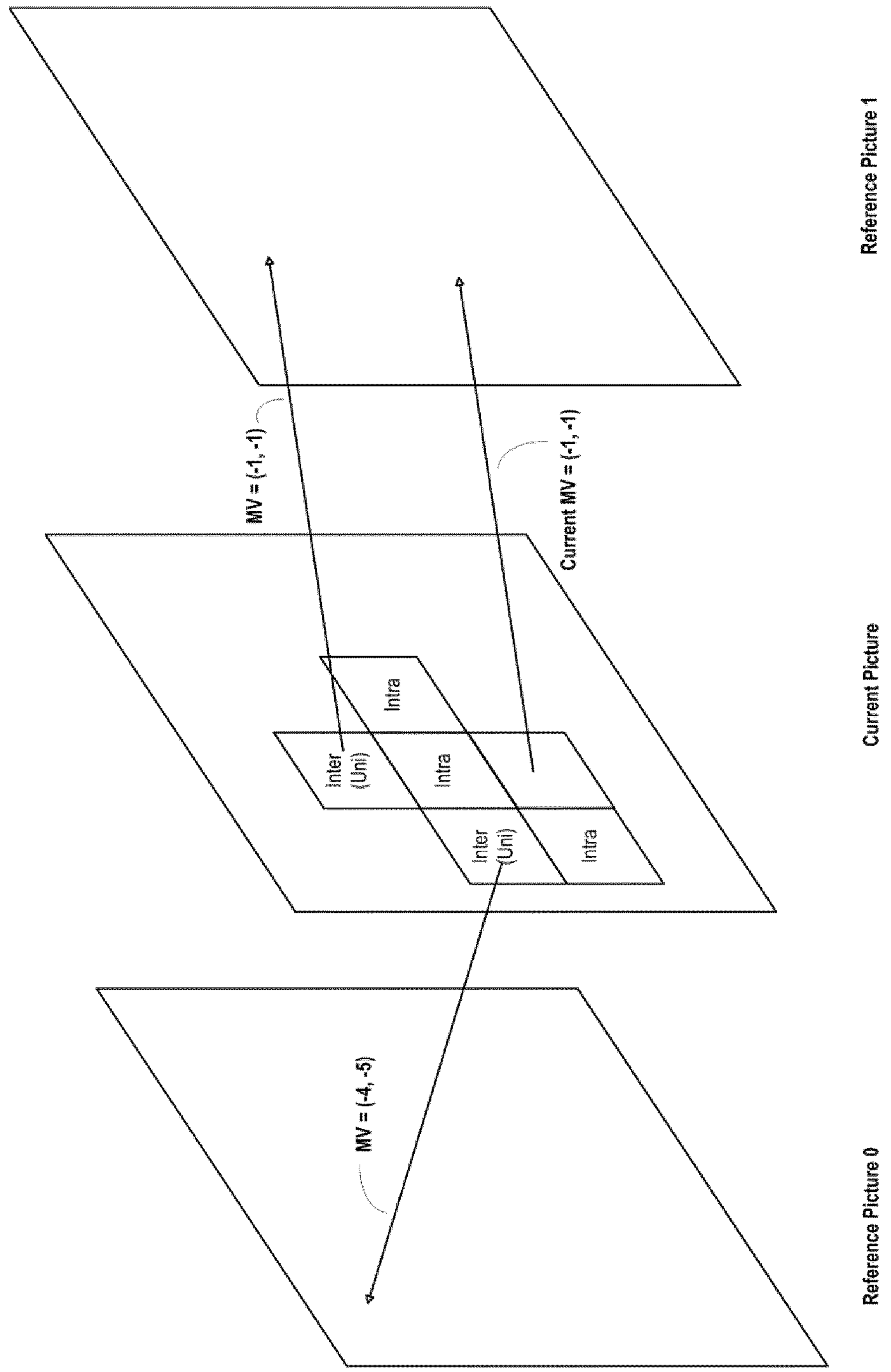
Reference Picture 1
MV = (-1, -1)
Current MV = (-1, -1)
Current Picture
Inter (Uni)
Intra
Intra
Inter (Uni)
Intra
MV = (-4, -5)
Reference Picture 0

FIGURE 5

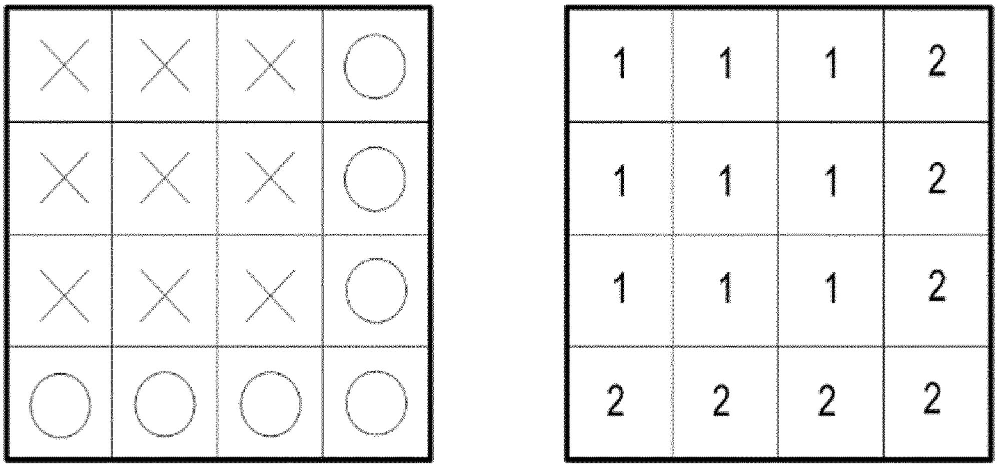

FIGURE 6

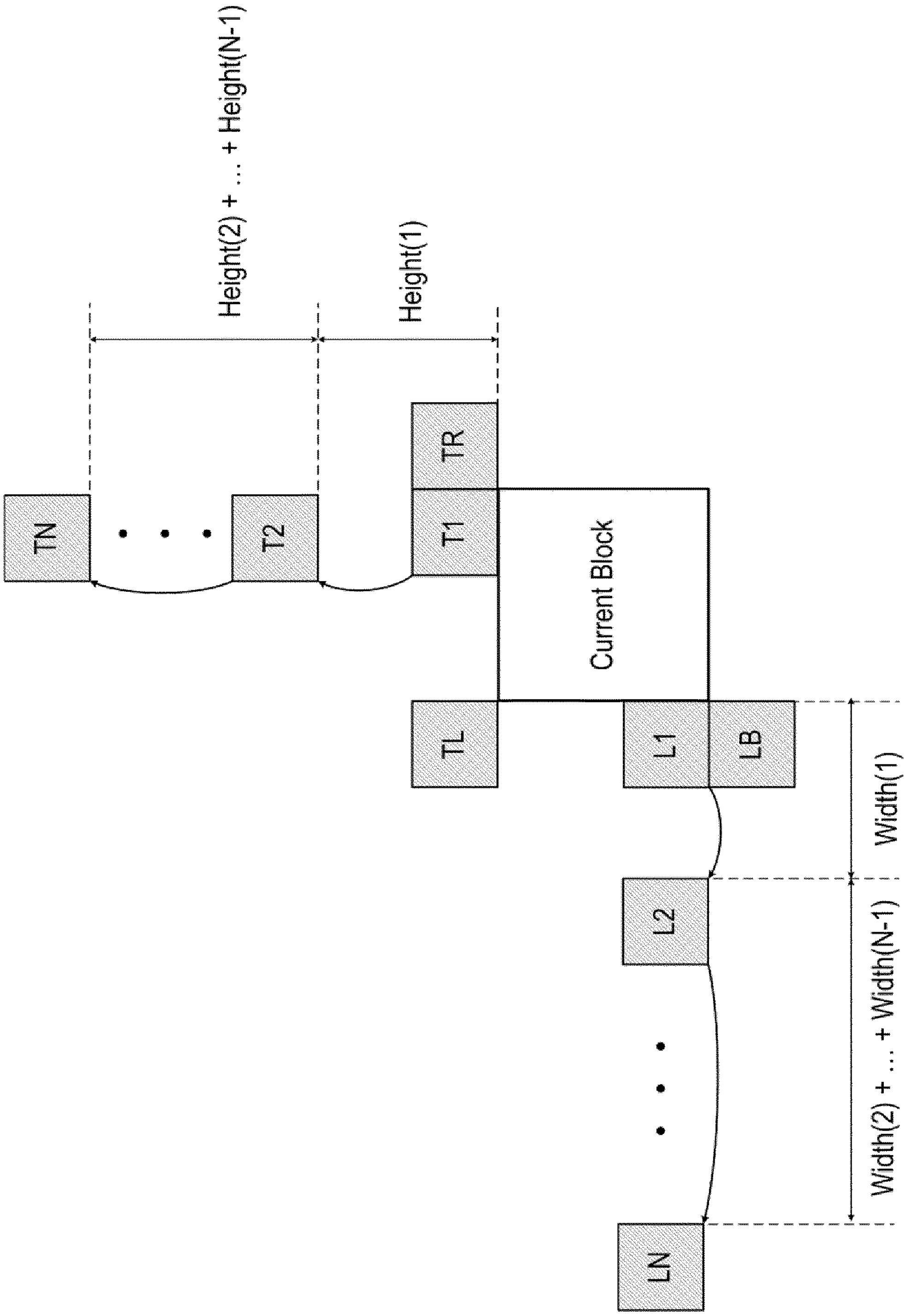
Height(2) + ... + Height(N-1)
Height(1)
TN
T2
TR
T1
Current Block
TL
L1
LB
Width(1)
L2
Width(2) + ... + Width(N-1)
LN

FIGURE 7

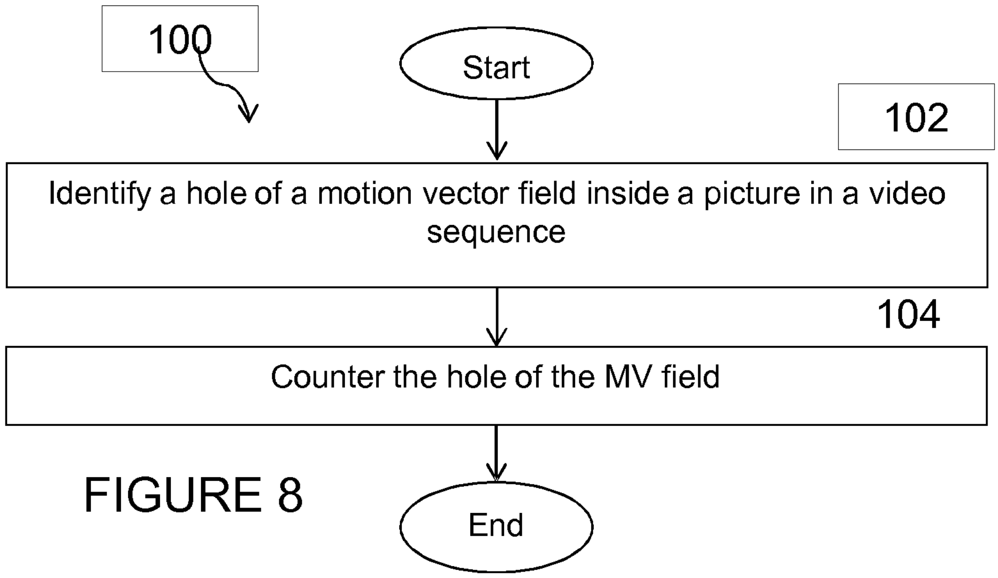

FIGURE 8

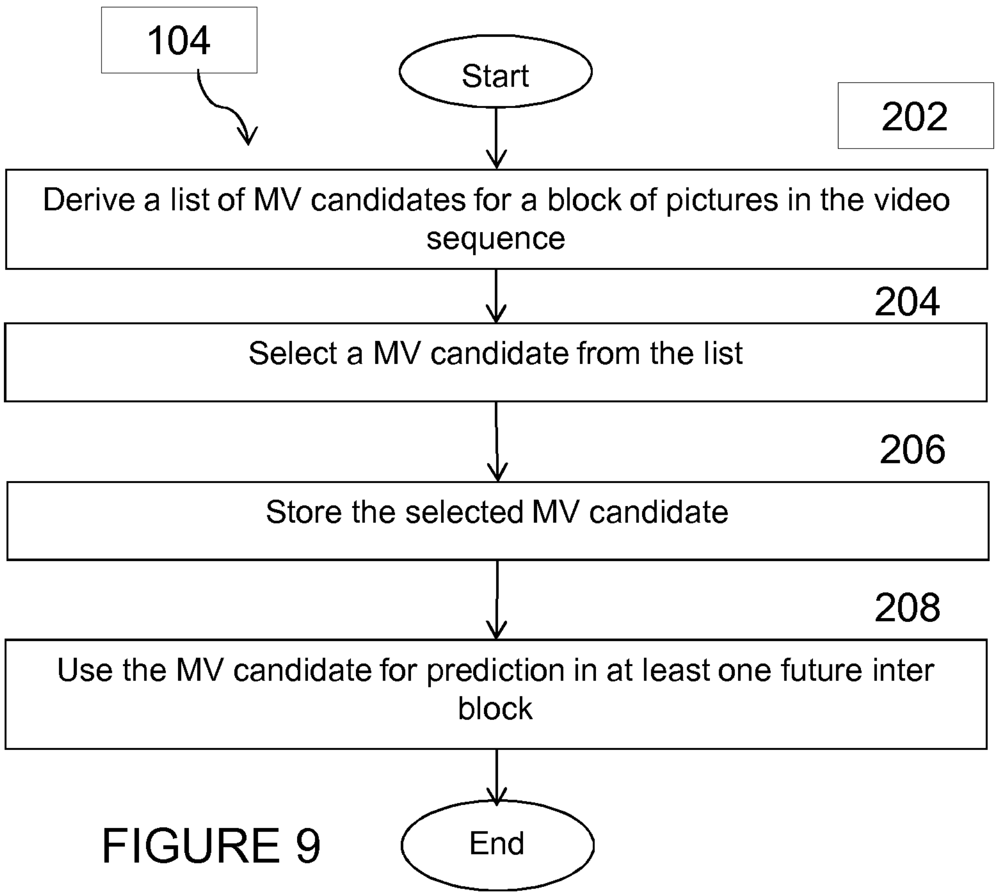

FIGURE 9

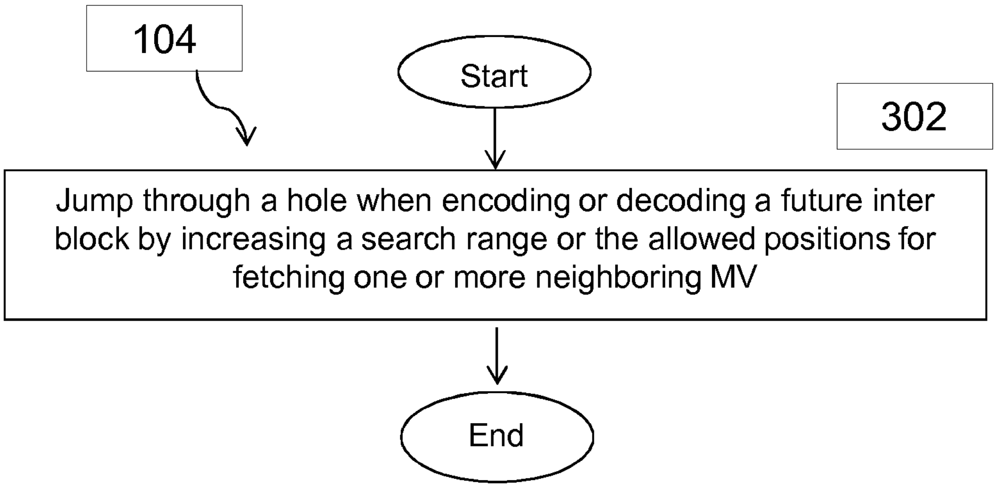

FIGURE 10

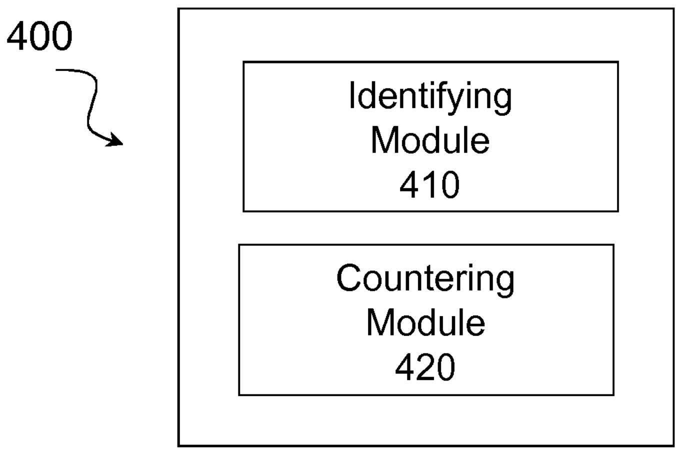

FIGURE 11

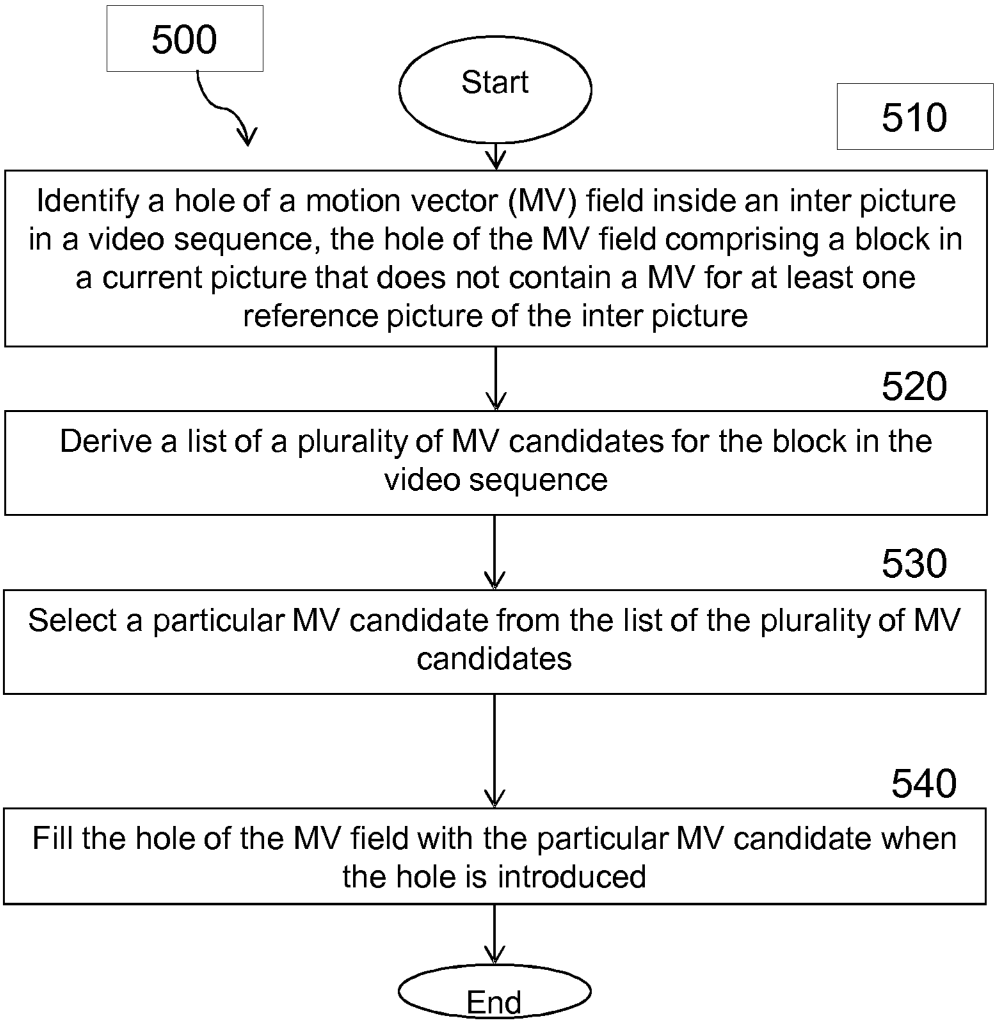
500
Start
510
Identify a hole of a motion vector (MV) field inside an inter picture in a video sequence, the hole of the MV field comprising a block in a current picture that does not contain a MV for at least one reference picture of the inter picture
520
Derive a list of a plurality of MV candidates for the block in the video sequence
530
Select a particular MV candidate from the list of the plurality of MV candidates
540
Fill the hole of the MV field with the particular MV candidate when the hole is introduced
End

FIGURE 12

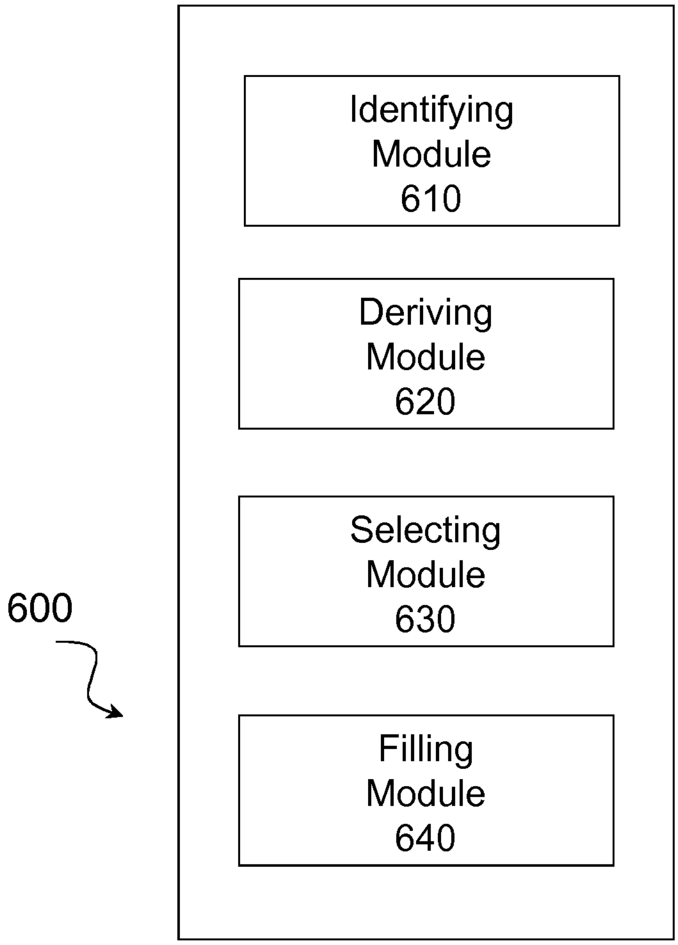
Identifying
Module
610
Deriving
Module
620
Selecting
Module
630
Filling
Module
640
600

FIGURE 13

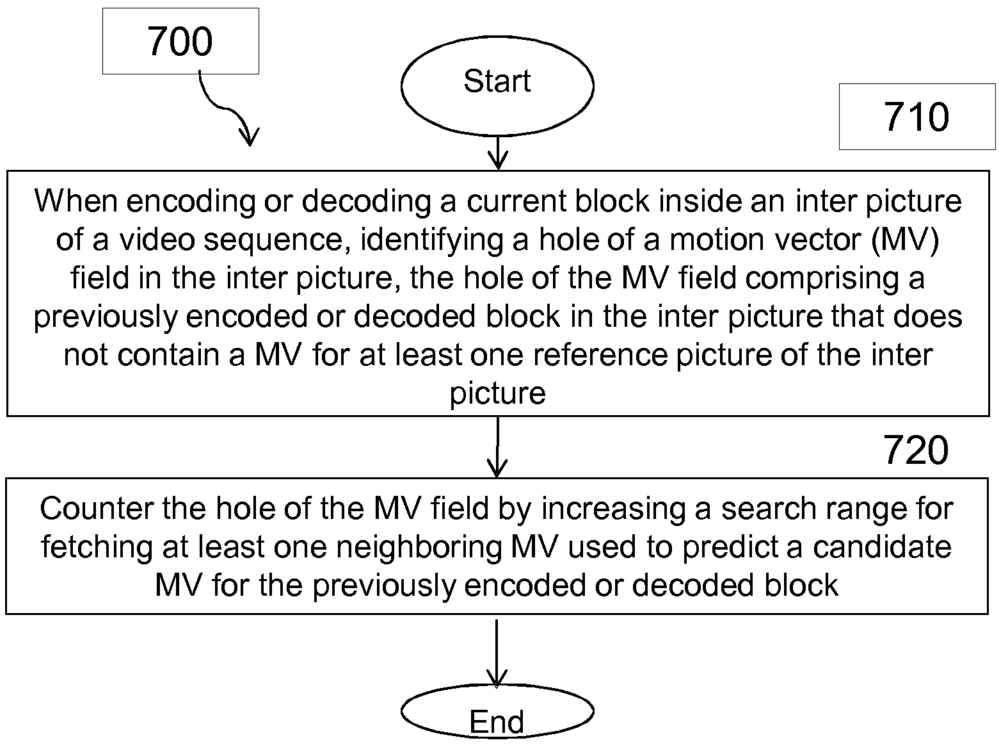

FIGURE 14

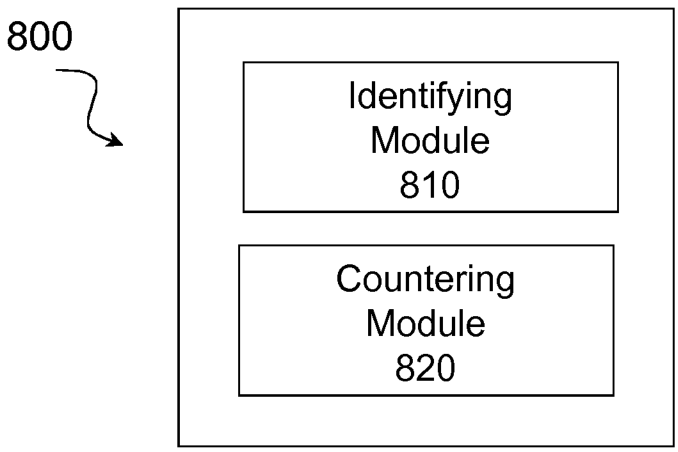

FIGURE 15

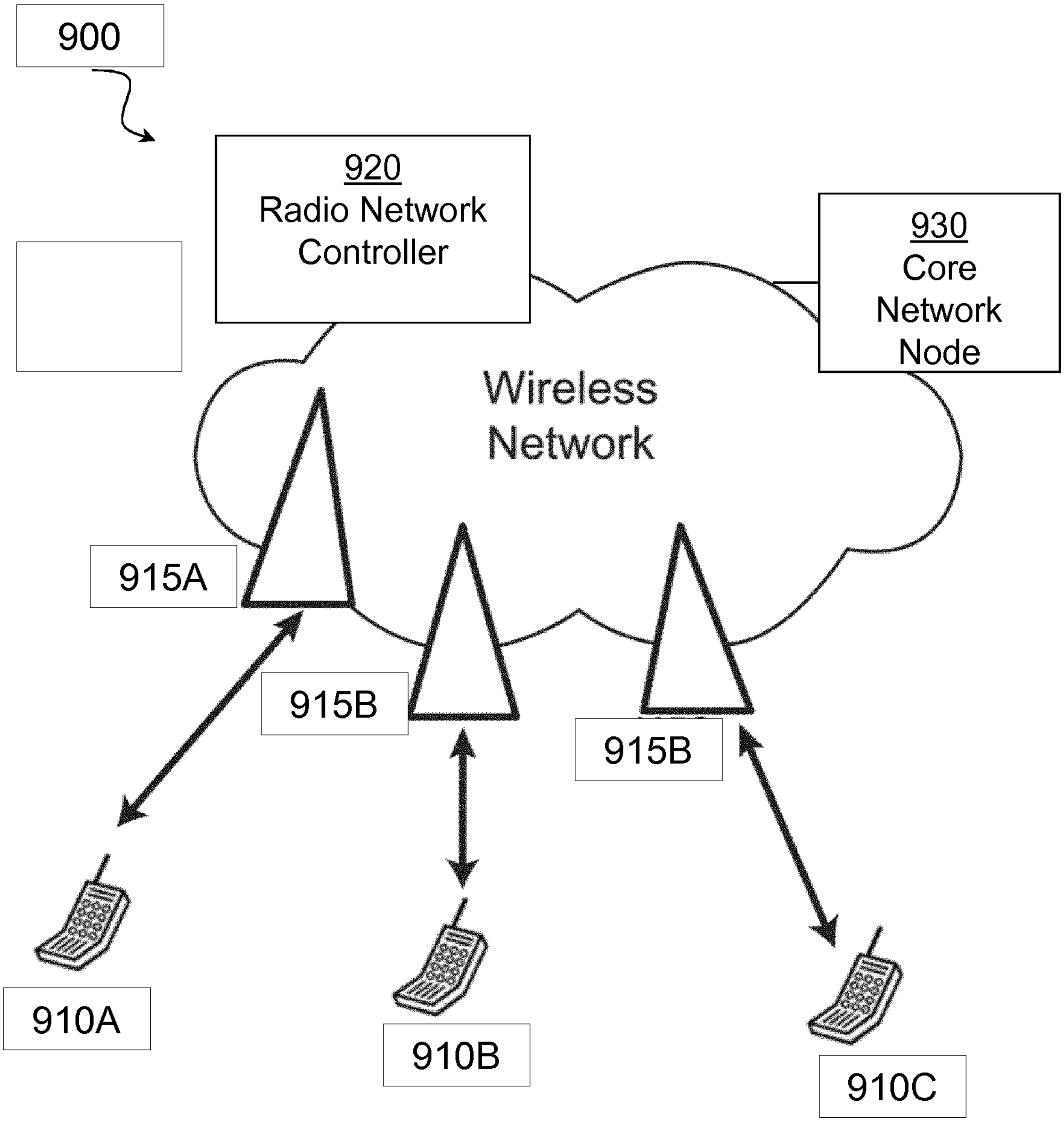
900
920
Radio Network
Controller
930
Core
Network
Node
Wireless
Network
915A
915B
915B
910A
910B
910C

FIGURE 16

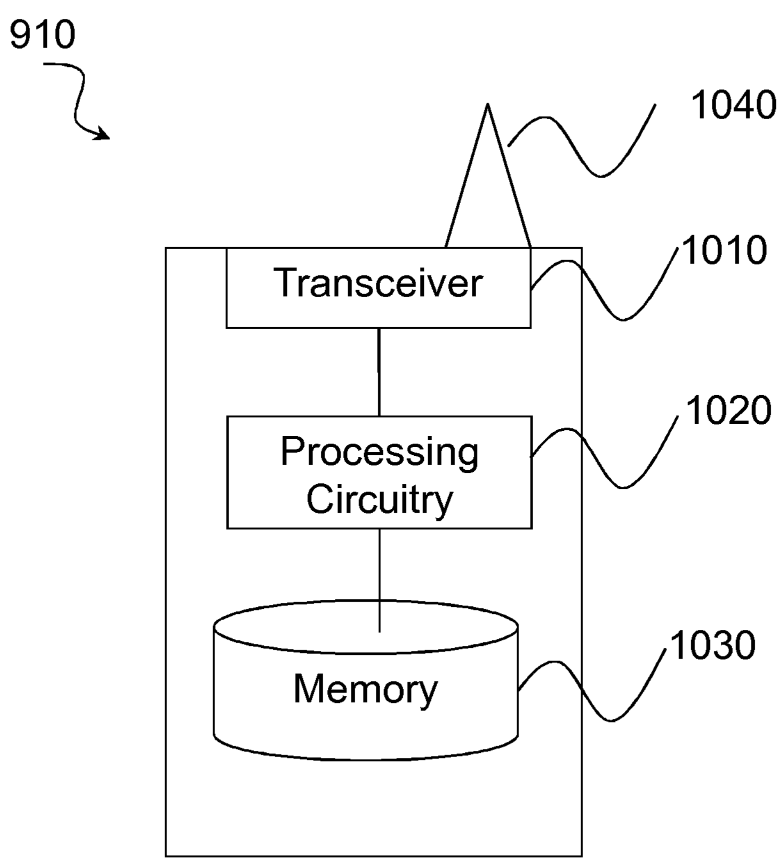
910
1040
Transceiver
1010
Processing Circuitry
1020
Memory
1030

FIGURE 17

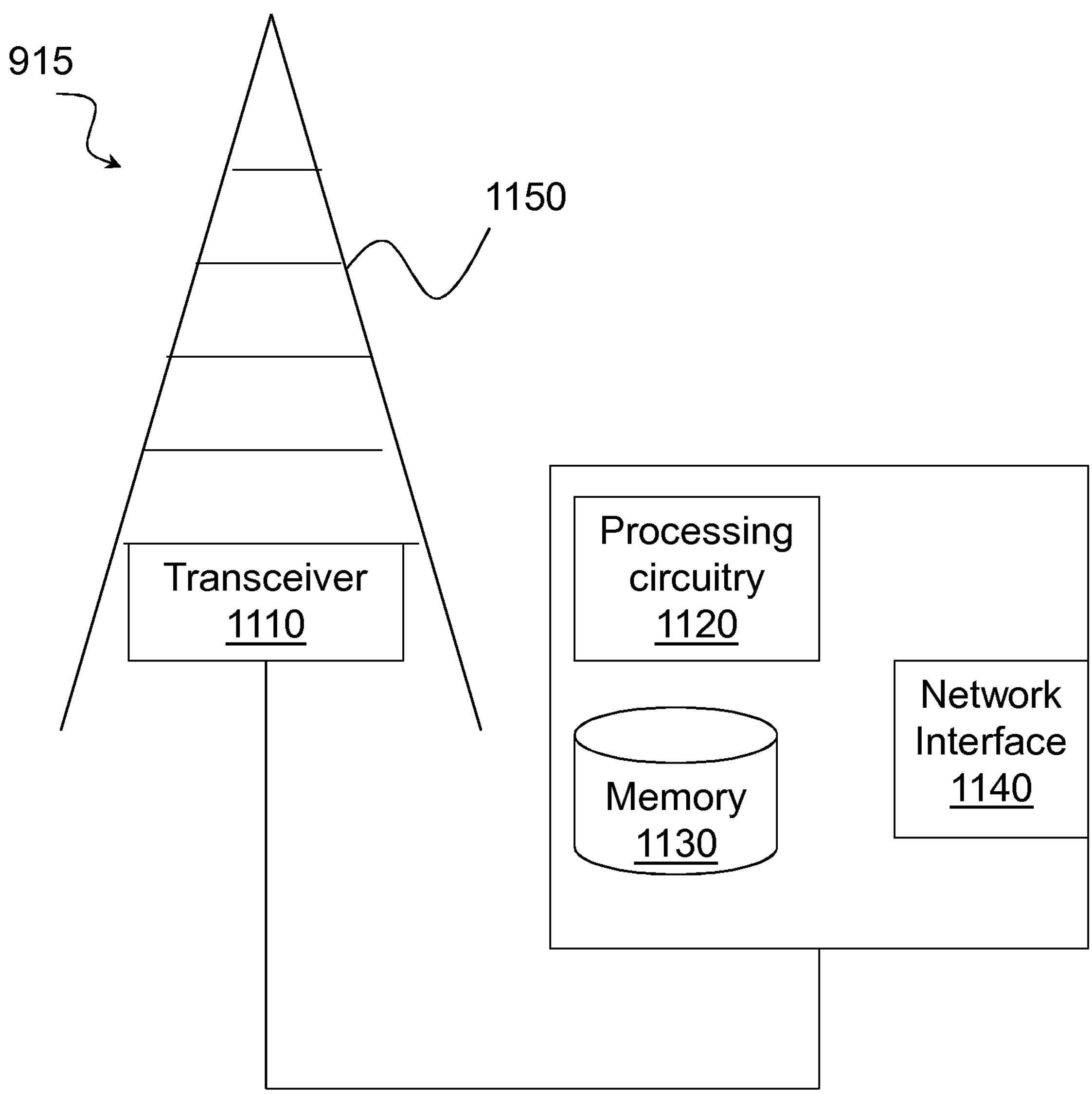
915
1150
Transceiver
1110
Processing
circuitry
1120
Memory
1130
Network
Interface
1140

FIGURE 18

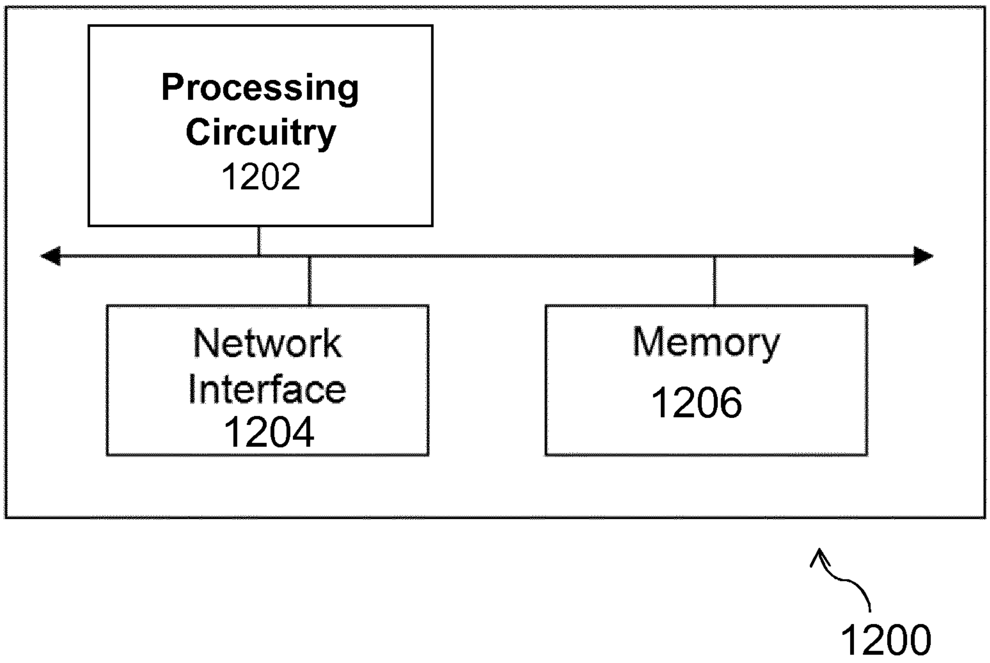
Processing
Circuitry
1202
Network
Interface
1204
Memory
1206
1200

FIGURE 19

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/076896

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04N19/52 H04N19/513 H04N19/105 H04N19/139 H04N19/176
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DA LIU ET AL: "An Improved Motion Vector Prediction Scheme for Video Coding", 1 January 2006 (2006-01-01), ADVANCES IN MULTIMEDIA INFORMATION PROCESSING - PCM 2006 LECTURE NOTES IN COMPUTER SCIENCE;;LNCS, SPRINGER, BERLIN, DE, PAGE(S) 598 - 605, XP019047743, ISBN: 978-3-540-48766-1	1,2,4-6, 12-17, 19-21, 27-29, 32-34, 37-41, 44-46, 49,50
A	the whole document	3,7-11, 18, 22-26, 30,31, 35,36, 42,43, 47,48

	-/--	

[X] Further documents are listed in the continuation of Box C.

[ ] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 November 2018	16/11/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Cyranka, Oliver

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	CHEN J ET AL: "Algorithm description of Joint Exploration Test Model 7 (JEM7)", 7. JVET MEETING; 13-7-2017 - 21-7-2017; TORINO; (THE JOINT VIDEO EXPLORATION TEAM OF ISO/IEC JTC1/SC29/WG11 AND ITU-T SG.16); URL: HTTP://PHENIX.INT-EVRY.FR/JVET/,, no. JVET-G1001, 19 August 2017 (2017-08-19), XP030150980, page 14 - page 15 page 18 - page 22	1,3, 7-16,18, 22-31, 35-43, 47-50 2,4-6, 17, 19-21, 32-34, 44-46
X,P	WANG SUHONG ET AL: "Enhanced Motion Vector Prediction for Video Coding", 2018 IEEE FOURTH INTERNATIONAL CONFERENCE ON MULTIMEDIA BIG DATA (BIGMM), IEEE, 13 September 2018 (2018-09-13), pages 1-5, XP033424052, DOI: 10.1109/BIGMM.2018.8499100 [retrieved on 2018-10-18] the whole document	1-50

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