A Review on Various Image Mosaic Techniques

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***Abstract* - Nowadays, most of the information is sent through internet. When data is being transmitted, security, confidentiality and integrity of data need to be ensured. Secure transmission of image has attained more importance as powerful computer tools are available for image processing. Also, for various reasons, there is a demand for lossless transmission of image. To achieve this, image mosaic techniques are used with the help of Cryptographic and Steganographic methods. In this paper, various image mosaic creation methods are reviewed and a comparison is made between them. Puzzle mosaic, which is another method of mosaic creation method used to solve some complex real time problems, is also briefly reviewed.**

Key words: - Image mosaic, Cryptography, Steganography, fitting, Colour transformation.

I. INTRODUCTION

The information can be in the form of text, image, audio and video. The data is transmitted. it should not be exposed to unauthorised users and also integrity of transmitted data should be assured. In some cases, the data can be compressed before transmission where little loss of data can be tolerated (lossy transmission, e.g: any type entertainment content). In some other cases the data should be transmitted in the uncompressed form. In this case, even a little loss of data will destroy the meaning of the entire content (lossless transmission e.g: medical images, military secretes, text files etc). If the channel used for transmission is unsecured, the existence of data being transmitted itself should be hidden (Convert communication).

To achieve all these, various types of Cryptographic and Steganographic methods are widely used.

Cryptography is a method, in which the data is encrypted before transmission using a secrete key. Only that user who has correct key can decrypt and view the secret information. The data to be hidden is usually a text or an image. In Cryptography the format of data is changed [14-15].

Steganography is a technique in which secrete information is written in to the cover object. The secret information can be any type of multimedia content (text, image, audio, and video) and cover object can also be any type of multimedia. Of these combinations “Hiding a text in an image” and “hiding an image in another image” are considered in the examples.

Mosaic refers to an art in which a larger object is built using smaller objects like tile, glass, stone etc. In image mosaic technique, a bigger image (mosaic / target image) is built using small pieces of the images called as “tiles”. The tiles can be re-arranged as an image, which can be the expected data. In some cases, the data is embedded in to tiles.

If it is a text, upon encryption, text becomes meaningless and hence even it is leaked to some unauthorised user, the data is still safe. Similarly, if an image is encrypted using a key, it becomes a noisy image. Though the contents are safe, a noisy image would unnecessarily attract hacker’s attention. So, the better way is to send the image “as it is” using “data hiding” techniques. Mosaic is one such technique in which the original secrete image is cut into small pieces of square or rectangular shaped tiles. These tiles are embedded into a target image. Information needed for recovering the secrete image is embedded into the target image. If more security is needed, recovery information is encrypted. Later, the target image (Cover image) can be transmitted using various Steganographic techniques. At the receiving end, only authorised users can reconstruct the secrete image using the recovery information and get the data hidden in it. This ensures double security.

The recovery information can be encrypted using algorithms like ECC, AES, etc.

The integrity of the data can be achieved methods like embedding “hash digest of the target image” or by embedding biometric information in to the target image.

Types of Image Mosaic Techniques

Following are the methods, which describes the creation of the mosaics and their uses.

A. Ancient mosaic technique.
B. Crystallization mosaic technique.
C. Photo mosaic technique.
D. Puzzle mosaic technique.

In (A) and (B), mosaic image is built from the tiles (small pieces) of the single secrete image. In (C), mosaic image is built using regularly shaped number of small images. In (D), mosaic image is built using irregular shaped (arbitrary shaped) images. Since (C) and (D) needs more than one image to build the mosaic, they are collectively called as “multi-picture mosaic”.

A. Ancient mosaic :

This method is mainly used to reconstructing the images of old objects (inscription, palm tree writings, embossed sculpture, and old scripture) of historical importance. For example, in order to digitise the information of an inscription, it is not enough to take a single photograph. In a single photograph, all the minor information cannot be recorded as the inscription is scratched, blurred, or broken. In this case, multiple photograph of the same scene is captured from various angles and distance. Suitable “tiles” are extracted. Though the tiles are extracted from multiple images, the tiles constitute the same image. Hence, the collected tiles are merged and a high definition mosaic image is built which records all the minor details of the inscription [13].

B. Crystallization mosaic

In this method, the secrete image is cut into small pieces called “tiles” and the target image is cut into small pieces called “blocks”. The goal is to construct the target image using the tiles of secrete image. The tiles are mapped in to the “matching blocks” based on some algorithms to construct a rough target image. Various colour transformations schemes are applied to improve the visual appearance of the image. Finally, tiles are rotated in various angles to reduce RMSE value between secrete image and target image. [1] – [6] and [8].

The secrete image is not compressed before it is being embedded in target image. Hence, nearly lossless recovery is possible, which is one of the primary advantages of this method. This method is called as “secret fragment visible mosaic”.

A variation of this method is used to blur the selected sensitive portion of the image using mosaics [7].

The target image may reside in a huge database or it may be randomly selected. This method mainly focuses on maintaining the similarity (accuracy) between secrete image and target image. The tiles can be of rectangular shape or of square shape. Fig. 1 shows the flow chart of the entire process. A comparison of various Crystallization mosaic techniques are done in TABLE 1.

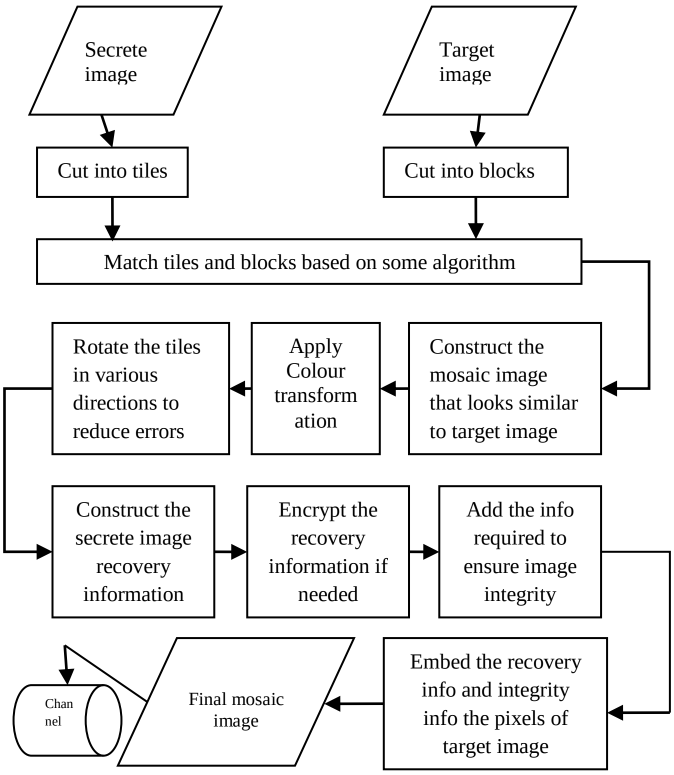

Fig. 1. Flow chart of Crystallization Mosaic

C. Photo mosaic

In this method, a target image is chosen and cut into small pieces (tiles). Target image is re-built using various “matching small images” which resides in a huge database containing thousands of small images. Each ‘tile’ is compared with the ‘small images’ in the database by using a strong searching algorithm. Later, the tile is replaced by a “matching” small image. This process is repeated for all the tiles of the target image and a complete target image is rebuilt by hundreds of different small images. Hence this method is called multi- picture mosaic [12].

When viewed from a distance, the mosaic image approximately looks like the target image. But when viewed in close–up, “small images used for re-building of target image” - are clearly visible. This discrepancy is intentional. The secrete data is loaded in to the tiles of this target image. Already a lot of discrepancy exist in the mosaic image and hence, embedding of secrete data by changing the few of the pixel values of the tiles is hardly noticeable. In some variations of this method, the tiles are slightly rotated to increase PSNR value.

D. Puzzle mosaic

In this method, an arbitrary shaped container image is filled using arbitrary shaped tile images. A database is built containing thousands of arbitrary shaped tiles with varying in size. In the first stage, tiles are roughly placed

(Overlaps and gaps are ignored) in the container image and later, their placement is re-aligned and refined. Finally, the images are trimmed to avoid overlaps and rotated to fill the gaps. Voronoi diagrams may also be used for deciding the place of tiles in the container image. The container image is just "best filled" and gaps do exist. But the outlines and edges of container image are strictly maintained while filling the tile images. Since the entire process is similar to solving a Jigsaw puzzle, this method is also called as Jigsaw mosaic. As many independent tile images are used to fill the container image, this method falls under the category of multi-picture mosaic. [9] – [11].

II. LITERATURE REVIEW

I-Jen Lai and Wen-Hsiang Tsai [1] proposed, a "Crystallisation mosaic method" in which mosaic is built by fitting fragments of secrete image (tile image) to the matching "blocks" of the target image. The target image is taken from the data base. The secrete image is divided into rectangular tiles. The average values of all the pixels of tile are taken and represented as R_c, G_c, B_c. The three colours are represented in 8 bit new quantisation scale as N_a, N_b, N_c and new pixel values are represented in quantised scale as R_c', G_c', B_c'.

"H factor" value of each block is calculated. H factor converts 3D colour is into 1D. Similar operations are done for "blocks" of the target image and H factor values are found out.

H factor value of "tile" and H factor value of all the "blocks" of target image are compared using "image similarity value method" [*m (s,d),* where 's' and 'd' represent the h factor value of tiles and blocks respectively]. For a combination for which 'm' value is highest, that block is treated as "similar" and mapping is done from tile to block. Using the same "Image similarity value method" suitable target image is selected from the database. As an alternative, Dijikstra or Greedy Search algorithm can be used. But Image similarity value method showed to give better result. The recovery information (L_R) is represented as a bit stream and embedded into mosaic image. As the size of the target image decreased RMSE (Root Mean Square Error) between secrete image and target image decreases. Recovery information is encrypted and hence without a correct key, it is not possible to rebuild the secrete image. Though, secrete mosaic image is "visible" to everyone, secrecy of data is ensured.

Deepthi G Singhavi and Dr. P. N. Chatur [2] proposed a method in which mosaic image is created by selecting an arbitrary target image. "Standard deviation method" is used, for fitting tiles of the secrete image to the blocks of the target image. It is advised that the target image should belong to same field as that of secrete image. If there is a size mismatch, secret image is resized to match the size of the target image. The secrete image is divided into rectangular tiles (3X4) and standard deviation of all the tiles is calculated and arranged in the ascending order. Similarly, standard deviation of all the blocks of target image are calculated and arranged in the ascending order. If at least 6-7 tiles and blocks are matched, then it is assumed that, target image is matched to the secrete image. Later, tiles are mapped (fitted) to the corresponding blocks.

"Colour transformation scheme" is applied to make mosaic image visually more similar to target image by changing the C Channel coefficients.

$$C_i'' = q_c\,[C_i-\mu_c]+\mu_c' \qquad (1)$$

Where,
C_i'' is the new C channel coefficient
q_c = standard deviation coefficient [$qc = \sigma_c' / \sigma_c$]
C_i is the C channel coefficient
μ_c is the mean.
σ is the standard deviation.

While colour transformation, if new C channel quotient values exceeds 255 (overflow) or takes a value less than Zero (underflow) the residual values are recorded. To further smoothen the mosaic image "tile rotation" scheme is applied at 90, 180, 270 degrees, which will result in less RMSE value. Secrete image recovery information is embedded into the mosaic image using LSB (Least Significant Bit) scheme.

Ya-Lin Li1 and Wen-Hsiang Tsai [3] proposed a method in which secret image is fragmented into tiles and fitted into blocks of an arbitrarily selected target image without the need of any image data base.

Mean and Standard deviation of all the tiles of the secrete image and the blocks of target image are calculated and arranged in ascending order. Later tiles are one-to-one mapped to blocks. Colour transformation scheme is applied on each tiles of the target image to change C channel coefficient, to match secrete image. The residual values are noted if overflow or underflow occurs. To give more visually pleasing effect and to reduce RMSE value, the blocks of target image are rotated at 90,180,270 degrees wherever needed. Secrete image recovery information is encrypted and embedded into mosaic image using LSB scheme. The secret image is recovered which is nearly lossless. This method is inspired from Lai and Tsai, but gives better result (less RMSE value) compared to Lai and Tsai method.

Asawari S Chavan and Amrita A. Manjrekar [4] proposed a method for information hiding using mosaic image which ensures data integrity also. A target image is arbitrarily chosen and resized as per the size of secrete image if needed. Unlike the other methods, the secrete image is divided into square shaped tiles and target image is divided into square shaped blocks. Tiles are mapped into blocks based on colour variation. Colour transformation method is applied on all the blocks of mosaic image, C channel coefficients are changed and residual values are noted if generated. The tiles of mosaic image are rotate if needed. This completes the mosaic image creation process.

The unique feature of this method is, a border is created for the mosaic image and a "metafile" (text + other type of information) is embedded using TBPC (Tree Based Parity Check) algorithm. A secrete recovery information is added using LSB method. Finally 128 bit "hash digest" is added to mosaic image to ensure data integrity. This mosaic image is transmitted over the channel.

Nishigandha V Gaikwad and Shilpa P. Metkar [5] proposed a mosaic creation method which mainly focuses on smooth and continuous mosaic image from the spectator's perception. This method employs SSIM (Structural SIMilarity method) for improving the visual perception quality of the image. Greater the SSIM value, "better" is the smoothness of final mosaic image and hence, less prone to hackers attack.

Mosaic image is created using the secrete image and an arbitrarily selected target image. Both secrete image and target image are broken into small pieces. The pieces of secrete image and target image are mapped, based on standard deviation method. Colour transformation method is applied and residual values are noted.

To reduce the RMSE value tiles of the mosaic image need to be rotated in various angles of rotation. In practical, the RMSE value can be less for more than one angle of rotation and hence it becomes difficult to decide the angle of rotation. To solve this ambiguity, the tiles should be rotated into that direction in which the final mosaic image looks more pleasant and smoother from viewer's eye perception. To measure this quantity, SSIM unit is used.

If 's' is the secrete image and 'r' is the reference image (target image), then..,

$$CC = \sigma_{sr}/\sigma_s\sigma_r \quad (2)$$

$$L = 2\mu_s\mu_r/\ \mu_s^2 + \mu_r^2 \quad (3)$$

$$C = 2\ \sigma_s\sigma_r/\sigma_s^2+\sigma_r^2 \quad (4)$$

Where, **CC** is the coefficient of linear relation between's' and 'r', **L** is the amount of luminance mean and **C** is the constant of similarity between two images.

$$SSIM = CC \text{ X } L \text{ X } C \quad (5)$$

The tile is rotated to that direction for which similarity index (SSIM value) is maximum. For a lesser value of SSIM, RMSE value can be more but it is ignored as the human perception experience of mosaic image is the main matter of concern in this method.

Meghana N and Chetan. H [6] proposed a method in which using secret image and a target image of user's choice, a mosaic image is created using fragments of secret image and target image.

Any arbitrary target image which resembles the secret image in colour/size is selected. The images considered are usually of size 512X512 or 256X256. Later these images are divided into 8X8 chunks using MATLAB commands. The chunks of secret image and target image are mapped using colour deviation method. Colour transformation is applied, residuals are noted, and tiles are rotated to get least RMSE value.

The secret image recovery information is built and is encrypted using a 64 bit ECC key (Elliptical Curve Cryptography). ECC key is short and efficient compared to other type of encryption methods like RSA and AES. It has been stated that generation of ECC key takes at least 15 times less time than RSA key.

The ECC encrypted recovery information is hidden in mosaic image using LSB method and later, mosaic image is sent across communication channel.

Yi-Hui Chen, Eric Jui-Lin Lu and Chu-Fan Wang [7] proposed a mosaic method in which only sensitive part of the image (called as Region of Interest –ROI) can be hidden using mosaic for the sake of privacy protection and limited access. Usage of this method is widely used in hiding the view of restricted areas in Google street view (areas of high importance such as defence settlements, administrative settlements), hiding obscene scenes in an image etc. The ROI is blurred using mosaics. Later, authenticated users who have the key are given access to the mosaiced ROI, to view original image in entirety.

If any ROI of any image need to be blurred (using mosaics), ROI is marked with 'Ones' and other regions are marked with 'zeros'. Using P-tree (Piano count tree), bSQ (bit sequential) is built. ROI is hidden by using "S" key and a mosaic factor 'α'. Higher the value of 'α' higher is the mosaic strength. (Blurred area becomes more 'unidentifiable'). Using the 'S' key, authorised users can view the mosaic image in its original entirety. PSNR (Peak Signal to Noise Ratio) of original image and reconstructed image will be the same.

Smitha Kuldiwar and Deepa Parasar [8] proposed a method in which, mosaic image created by taking an arbitrary target image and using standard deviation method. Mosaic image is later Watermarked for security purpose and compressed. Watermarked is done using DWT (Discreet Wavelet Transform) and PCA (Principal Component Access) transform technique.

The secrete image is divided into tiles and target image into blocks. The mean and standard deviations of tiles and blocks are calculated, arranging in ascending order, one-to-one mapping is done from tile to blocks, colour characteristics are changed, residual values are noted and tiles are rotated (if needed) to reduce RMSE. Two dimensional DWT is applied on mosaic image and Watermark is embedded into high frequency sub band

. Before embedding the Watermark, PCA (Principal Component Analysis) is done and suitable components are decided to which Watermarking can be done. At last stage, images compressed using Huffman / Arithmetic coding.

Watermark ensures the high security to the mosaic image. For breaking the Watermarking, the hackers have to try n! permutations. For a 768x1064 image which is divided into 8X8 blocks, the attackers has to try (768x1024)X(8X8) =12288! permutations. Trying these many combinations is practically impossible and hence, Watermarking ensures high security to the mosaic image.

Junhwan Kim and Fabio Pellacini [9] proposed a "multi-picture" mosaic technique in which an arbitrary shaped "container image" is filled with arbitrary shaped tile images, so that the container image is packed as compactly as possible. Tile images are rotated and deformed if needed for smooth visual effect. In the proposed method, a database containing 900 arbitrarily shaped tile images varying in shape, size and colour, is built. Tile images of similar or near colour / shape are taken and filled in container image like a Jigsaw puzzle. Hence, this method is also called as puzzle mosaic. The concept of puzzle mosaic is basically inspired by an Italian painter Arcimboldo. He painted "composed head" where face is painted using vegetable images. To get an optimal solution for Jigsaw puzzle mosaic, an energy function E is defined as follows:

$$E = E_C W_C + E_G W_G + E_O W_O + E_D W_D \qquad (6)$$

Where W_x indicates weight, C indicates colour of the tiles, G indicates gap between the tiles, O indicates overlapping of the tiles, and D indicates deformation of the tiles. The optimal solution is the combination for which E value is the minimum. By varying the weights, different types of (visually different) mosaic image can be formed.

In the beginning, the tiles taken from the database and are roughly placed in container image. Their placement is verified and adjusted thereafter. Finally, tiles are deformed to avoid overlap (if exist) and rotated to fill the gaps. Every time, the boundary of container image is strictly maintained. Whenever a tile need to be placed in the container, it is tried in all possible places using CVD (Centroid Voronoi Diagram) method, and right position is chosen based on "Geometric hashing method". Each time, after a tile image is placed in the container, a new container image is created by subtracting the tile image.

This method takes 10 minutes to 2 hours for "filling" the container image depending upon the complexity and hence can be applied for less denser container image (soft packing).

Yang zhan-long Guo bao-long [10] proposed, another puzzle mosaic method inspired from JIM (Jigsaw image mosaic), called as TIM (Tile Image Mosaic). This method uses "Antipole bisector tree" for reducing the time for proximity / similarity search. The irregular shapes are defined using "Centroid Radii" scheme. In this method also, an arbitrary shaped container image is "best filled" with many arbitrary shaped tile images by searching the tile images from the database, but it takes very less time for searching the database compared to JIM due to the usage of Antipole tree method.

In the first stage, edges are detected from the container image (outline image is formed). Voronoi diagram of same size of container image is created (by placing the sites randomly). Outline image and Voronoi diagram is superimposed to give a final composite image. The composite image also contains irregular shaped Voronoi areas.

These irregular shapes are mapped into Centroid-Radii metric plane. This plane contains the plot of length of radius v/s angle of rotation. This plot is 'rotation independent and 'starting point independent'. Similar plots will be done for all the tile images in the database.

Using Antipole proximity search method, matching tiles selected from database in less time and fill to the suitable place of the container. Rotations and deformations (changing the shape) of tile images are done to fill the gaps and to avoid the overlapping. Fitting time varies from 5 seconds (199 tile images) to 114 seconds (3079 tile images).

Gianpiero Di Blasi, Giovanni Gallo and Maria Petralia [11] proposed PIM (Puzzle image Mosaic) inspired from JIM (Jigsaw Image Mosaic). It gives better solution in less computational cost by employing Antipole proximity query. In PIM also, an arbitrary shaped container image is filled with hundreds of arbitrary shaped tile images taken from a database.

The "Direction guideline image" (A rough outline excluding the isolated points) is extracted from the container image. Voronoi diagrams of container image size are constructed by randomly placing the "sites". Directional guideline image is superimposed on Voronoi diagram. As a result, new Voronoi areas are formed wherever directional outline intersects the exciting Voronoi areas. Now, these irregular shaped sub divisions need to be filled with tile images taken from the database.

Based on Antipole proximity query, matching tiles are chosen from the database and filled in the suitable place of the container image. At the final stage, colour transformation, rotation and deformation of tile images is done wherever necessary. This method can be further expanded to 3D. For a database containing 1025 tiles, this method will take 192 seconds (275X276 size) to 293 seconds (899X615 size).

Arthe Henriette Pascaline, Li Chun Fong Christopher, Maleika Heenaye-Mamode Khan and Sameerchand Pudaruth [12] proposed a very different mosaic technique called "photo-mosaic" method. Here an "art like" mosaic image is created by selecting regular shaped small images called tiles. Tiles are of the size 8X8, 16X16, and 32X32 residing in a database. The database may contain up to 10000 tile images.

When viewed from certain distance, the mosaic image resembles and gives the appearance of the target image. But when viewed in close up, individual small pictures (tiles) are clearly visible. This difference is intentional (If no difference is observed in close up, it means that, the mosaic image is exactly same as the target image and hence, unfit for the data hiding). To these tile images, information bits are embedded using LSB method.

An arbitrary target image is selected and it is cut into regular shaped pieces. The pixel values of each fragment of target image are compared with small images of database. If pixel match is more than 50% in their intensity value, than that tile is treated as "similar" and fitted to the place of the fragment of target image. This process is repeated for all the fragments of the target image and thus, a mosaic of target image is created. Later, a text or image "payload" is embedded into each tile image of the mosaic by LSB method.

A target image of 1000X1000 pixels can accommodate up to 3.75 lakhs of ASCII characters (approximately 69000 words!!). Only regular shaped target images (which are multiples of 8, 16,
and 32) are preferred. The time for fitting process may take up to 5.5 hours (8X8 size, 34560 tiles), but retrieval process is instantaneous. Processing time may be reduced by employing histogram matching and pixel based matching algorithm.

TABLE I. COMPARISON OF VARIOUS CRYSTALLIZATION MOSAIC METHODS

Characteristic Feature	**Ref [1]**	**Ref [2]**	**Ref [3]**	**Ref [4]**	**Ref [5]**	**Ref [6]**	**Ref [8]**
Method used for Target image selection	"Image similarity value" [m(s,d)] applied at image level or Dijikstra algorithm	A target image belonging to the same field is selected	Any randomly selected Target image.	Any randomly selected Target image.	Any randomly selected Target image.	Target image of same colour, size and background	Any randomly selected Target image.
DB needed?	Yes	Yes	No	No	No	No	No
Resizing of images needed?	No information	Yes, secrete image need to be resized	No information	Yes, Target image need to be resized	Yes, Target image need to be resized	NA	No information
Method used for match a block to a tile	"h factor" and image similarity value	Mean and Standard deviation method	Mean and Standard deviation method	Mean and Standard deviation method	Mean and Standard deviation method	Mean and Standard deviation method	Mean and Standard deviation method
Are tiles rotated?	No information	Yes	Yes	No information	Yes	Yes	Yes
Reason for rotation	NA	To reduce RMSE value	To reduce RMSE value	NA	To increase SSIM value	To reduce RMSE value	To reduce RMSE value
Is recovery information encrypted?	No	No	No	No	No	Yes, using an ECC key	No
Steps taken for data integrity.	No	No	No	Yes, 128 bit hash digest	No	No	Yes
Comments and special features	Huge BD needed and result depends on number of images in DB	Target image should be double the size of Secrete image	-	1. meta file is created out of recovery information and embedded in "created borders" using TBPC algorithm 2. Square shaped ties and blocks	1. Main focus is on smooth visual perception f the mosaic image by human eye 2. RMSE value may get increased for increased value of SSIM	Large sized images are used	1.Watermarking is done using DWT and PCA method 2. Mosaic image is compressed using Arithmetic coding

III. CONCLUSION

Various methods of mosaicing techniques are discussed. Achieving data security and ensuring data integrity by using Cryptography, Steganography and Image Mosaics are discussed.

It is also noted that some of the mosaic creation techniques will take considerable time for execution and needs huge database of tile images. An arbitrary target image can also be selected in some methods. For smooth visual effect of image and to reduce various errors colour transformation schemes need to be applied. This leads to added computational work.

Building a mosaic image directly from the noise image (encrypted secrete image), creation of second level mosaic image, clubbing the basic methods of mosaic techniques for better results, employing more efficient algorithms for data security and integrity can be considered for future scope of improvements.

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