

# **A Method And System For Network Based Automatic And Interactive Inspection Of Vehicles**

## **Field of Invention**

- 5     The instant invention relates to a method and system for network based automatic and interactive inspection of vehicles. It generally relates to capturing multiple images of the vehicle and calibrating the images to form a composite image or a series of video and inspect the vehicle for any unidentified object.

## **10     Background of the invention**

- The need for security at commercial and civilian establishments can never be ignored. Recent bomb attacks have made it important now to detect every possible place where bombs can be placed. In recent times, terrorists have been known to use the underside of vehicles to plant  
15    explosives and for smuggling objects across security checkpoints. Apart from this, legitimate users of the vehicles and the establishments have also been known to smuggle out goods/documents by hiding them in the underside of vehicles. Also cross-border human trafficking has been done in certain cases by hiding people in the underside of vehicles. Hence the need for a system to facilitate the easy inspection of the underside of vehicles to detect any hidden objects.

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      Presently inspection of the underside is performed using inspection wells, or inspection mirrors predominantly. Certain establishments also use more advanced tools like camera equipped with lighting means to inspect the underside.

- 25    **GB2249690** proposed to 'image the underside of a vehicle using a TV monitor connected to a camera set into a pit or mounted in a hump in the road over which the vehicle travels' with a wide angle camera which produces line or strip outputs as the vehicle moves over the hump.

- GB2258321** proposed to use a line-scan camera looking up at the vehicle surface through a mirror  
30    in order to reduce the height of the underground unit.

      Certain companies also supply a video based viewing system which consist of four or more cameras arranged transversely, while certain other companies offer systems which try to provide an image of the underside through use of camera equipped with wide-angle lens.

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However, all the above systems have multiple disadvantages in terms of operational and security viewpoint. The adjustable camera plus light viewer system is just an advanced version of the inspection mirror; and hence most problems inherent in the inspection mirror like viewing only parts of the vehicle, tedious operation, large inspection times, unreliable, etc are also present in with the inspection camera system. The video viewing systems presents videos of the vehicle underside; the complete underside is not visible at any point in the video. Hence it is difficult for the operator to form a complete mental picture of the underside and determine if there is any abnormality in the underside. The systems which offer composite images underside images for inspection are among the best in the whole group; providing a complete view of the vehicle underside in a single image. However, most of these systems provide very little or no control to the operator in terms of interactively inspecting in greater detail, the image so provided. Apart from this all these systems also face the problem of hidden areas in the underside because the cameras always look up at the underside at a particular angle, usually vertically up, only.

Apart from the need for security, there is also a need to inspect vehicle surfaces for any defects or abnormalities from a manufacturing and maintenance point of view.

Both GB2249690 and GB2258321 produce a composite image of the vehicle underside as output of the system.

EP1482329A1 describe a means of automated image comparison but their method detects prominent vehicle features like wheel location, wheel-base, etc to index the database and also subsequently for the image comparison purposes. Also their method assumes that multiple instances of vehicle underside images can be aligned together by a simple translation.

## **Objectives and Summary of the invention**

It is an object of the instant invention to obviate the above drawbacks and provide a method and system for network based automatic and interactive inspection of vehicles.

It is another object of the instant invention to provide a composite image and video, if required, of the vehicle which captures every portion of the vehicle.

It is yet another object of the instant invention to automatically adjust the intensity and improve the resolution of the captured image.

It is further an object to compare the images captured, with prestored images.

5 The instant invention provides a method for network based automatic inspection of vehicles comprising detecting the arrival of a vehicle near a vehicle inspection system by a first sensor in said system, initiating said system by said sensor, detecting the location and time instants of said vehicle at predefined and configurable points and providing point readouts for said location detection, capturing images of said vehicle as the vehicle moves by a set of image capturing means, transmitting said images, detected location and time instants to a computing system,  
10 processing the captured images using said time instants and detected locations, automatically adjusting the intensity and improving the resolution of the processed image, displaying, inspecting and storing said processed images, analyzing a user defined portion of the composite image, if desired, and detecting the exit of vehicle and deactivating said vehicle inspection system by a second sensor.

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The invention also provides a system for network based automatic inspection of vehicles, wherein said system comprises a vehicle inspection system, said system including a first sensor for detecting the arrival of a vehicle near said system and initiating the system, means for detecting the location of the vehicle and instants at predefined points, a set of image capturing means for  
20 capturing a plurality of images, and a second sensor for detecting the exit of vehicle and deactivating said system, a computing means, said means including processing means for processing the images captured by said image capturing means using said detected location, means configured for automatically adjusting the intensity and improving the resolution of the processed image, means for displaying, inspecting and storing said images, and means configured  
25 for analyzing a user defined portion of the composite image, if desired, and transmitting means for transmitting said images to said computing means.

It also provides for a computer readable recording medium for storing a computer program to cause a computer to perform the steps of detecting the arrival of a vehicle near a vehicle inspection  
30 system by a first sensor in said system, initiating said system by said sensor, detecting the location and time instants of said vehicle at predefined and configurable points and providing point readouts at said location, capturing images of said vehicle as the vehicle moves over the inspection system by a set of image capturing means, transmitting said images, detected location and time instants to a computing system, processing the captured images using said time instants and detected  
35 locations, automatically adjusting the intensity and contrast for improving the visual clarity of the

processed image, displaying, inspecting and storing said processed images, analyzing a user defined portion of the composite image, if desired, and detecting the exit of vehicle from the inspection system and deactivating said vehicle inspection system by a second sensor.

## 5     **Brief description of the accompanying drawings**

**Figure 1** relates to the overview of the components of the vehicle detection system.

**Figure 2** describes the multiuser architecture of the system.

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**Figure 3** shows the top view of the vehicle detection system.

**Figure 4** describes the method of the invention by a flowchart.

15     **Figure 5** shows the various locations of a vehicle at for which time instants of entry/exit are detected.

**Figure 6** shows a calibrated image created from uncalibrated image.

20     **Figure 7** shows the image being divided into local sub images for automatic adjustment.

**Figure 8** shows the current image comparison result.

**Figure 9** shows a computing system.

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## **Detailed description of the drawings**

The instant system can be divided into three parts

- vehicle detection and imaging system (V),
- 30     - computing means (C), and
- transmission means for communicating between the above two.

An overview of the vehicle detection system is described in figure 1. It houses a plurality of cameras for imaging the vehicle surface. These cameras are covered for protection (10). There is a  
35     slit covered by a transparent sheet (11) over the camera, so as to enable it to capture the image.

Another array of camera is below the sheet (12). The camera captures the image through a mirror and light assembly (13). The mirror is arranged at a suitable angle so as to reflect the image of the vehicle to the camera, which is placed below sheet (12). The light assembly helps illuminate the surface of the vehicle for which the image is to be captured. The assembly may also incorporate means like a reflective sheath to focus the light and/or diffusion means to optimally adjust the quality and quantity of lighting. The kind of lighting and the intensity thereof would depend on the kind of cameras used. If low light cameras are used lighting may not required at all. The cameras include line-scan and area-scan cameras fitted with lenses capable of capturing the complete width of vehicles. The vehicle can be anyone from passenger cars and other small vehicles to military trucks and trailer trucks, trains, etc driving over the vehicle detection system.

The cameras below sheet (11) are located at strategic positions in order to view regions of the underside which are not easily visible in the central camera array, due to the view angle of central camera and the fact that the underside of most vehicles are nowhere near flat and consist of many cavities, nooks and other structures at varying heights.

Array of sensors (S1 and S2) are used to provide inputs about the presence/absence of the vehicle over the scanning unit at any point in time. A sensor array, comprising of sensors placed at different points in the vehicle track may be used to determine the average instantaneous speed of the vehicle. Sensors may be of different kinds: induction loops, load-cells or pressure sensors, proximity sensors, sonar or ultrasound sensors, laser rangefinders, infra-red sensors, etc.

The sensors detect the arrival of the vehicle and initiate the vehicle detection system. They also detect the location of the vehicle at various time instants, using which the images captured by the cameras, are calibrated and a composite image is formed. The sensors also detect the exit of the vehicle to deactivate the system.

The captured images are sent by transmission means to a computing means (15). This can be any electronic device, which has a display, an input means, and image-processing means and is configured for multitasking. The input means may include touch panel, voice recognition module and character recognition module.

The system is multiuser system and is networked based. **Figure 2** describes the architecture. Multiple users (U1...Un) sitting at remote locations can access the images captured or the

composite image formed at the computing means. The vehicle, whose image is being captured, can be viewed at real time from the remote locations.

The vehicle (14) approaches the vehicle detection system (V) and the system captures the images.

5 The images are sent to the computing system (C1) which, if needed transmits it to other computing systems (C2) in other remote areas through transmission means. Such transmission may include the network. The users may also access the database at the various computing systems which have the previous images of the vehicle. This may be explained as, if a vehicle X reaches a location L1, and it has previously been detected at location L2, the user may compare the images  
10 captured presently with the images captured and saved at location L2. Accordingly a vehicle can be monitored from many places as and when required.

The vehicle detection system on the whole, from top, can be seen in **figure 3**. A vehicle can be seen approaching the system, which is further connected to the computing system.

15 The computing system includes a processing platform which might be any kind depending on the data-rates from the various cameras and the kind of operation to be performed on the video streams (see below for details of the various options), ranging from low-end processors like x86 or ARM, etc to a high-end Pentium, AMD Athlon, IBM PowerPC, etc which is dedicated for this  
20 purpose. In certain cases, multi-processor configurations like the ones used for servers or high-end computations could also be used. The processing platform may have several hardware interfaces like parallel port, serial port, PCI, ISA, IEEE1394, USB, PS/2, etc. not all of which might be used. The processing platform may have several software/firmware layers like OS, drivers, software specific to vehicle inspection, software and libraries for other applications, etc.

25 The communication link between the computing system and vehicle detection system may be any of Ethernet, RS485, USB, RF, InfraRed, BlueTooth, 802.11, GPRS, CDMA, etc.

The computing system houses various modules. It has a module, which helps in image calibration and helping form a composite image. In case of video images, it helps in mosaicing.  
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It runs a graphical user interface (GUI), which displays the images, helps in accessing previously stored images and videos, comparing the images and giving the appropriate result. The computing system also has means to identify the make and model of the vehicle.

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The computing system also automatically adjusts the brightness/contrast and the intensity of the image. This is as per the input by the user about the desired intensity. The user may enter the range of desired brightness, which is configurable. The intensity of the image is also adjusted as per the distance of the vehicle from the ground i.e. the varying ground clearance. The vehicle parts close to the light source get brightly illuminated, whereas the faraway parts remain dark. Accordingly the intensity of the parts can accordingly adjusted. Also, a user may desire to inspect a particular portion of the image, corresponding to a particular area of the vehicle, which may be suspected. The computing system provides the facility of selecting a particular portion of the image and adjusting its intensity as desired.

The computing system also houses a module for automatically improving the resolution of the captured image.

The functionalities of above modules have been described in detail in the description of the figures.

**Figure 4** describes the working of the instant invention through a flowchart. The approach of a vehicle is first detected by the sensors installed. They send signals to initiate the vehicle detection system. A light assembly, cameras and the array of sensors are activated instantly.

The vehicle passes over the vehicle detection system. The system automatically adjusts the captured images to compensate for the varying speeds of the vehicles. The sensors detect the location of the vehicle over the system at various time instants. The cameras capture the image of the vehicle. As the vehicle moves away from the system, the captured images and time instants are sent to the computing system. The computing system does the image calibration. A composite image is formed. This image is then inspected automatically by the system for any unidentified part or manually. The images are stored in a database.

The vehicle detection system also captures images of the occupants and the license number of the vehicle. The license number is extracted from its image. It is seen if any image of the same vehicle already exists in the database. The images may then be matched.

The vehicle is allowed to go if the computing system shows an Ok status for the vehicle. The sensors detect the exit of the vehicle and deactivate the system.

The image calibration done by the instant method is described below.

The camera(s) take multiple images to form the composite image. These camera(s) might be line-scan cameras or area-scan cameras. In either case, the frame rate of the camera is fixed for a particular site, and hence the number of images captured by the main camera(s) would essentially  
5 be dependent on the time for which the vehicle is over the inspection area. If the time taken by the vehicle is larger the number of images would be large and conversely if the vehicle takes less time to cross the inspection area, the number of images would be less.

Hence there is a need to calibrate and normalize all the images captured by the system to bring  
10 them down to the same scale, such that images of the same make and model are similar in length and width. Calibration can be done by computing the velocity of the vehicle at different points along the length of the inspection area and using these velocity inputs to adjust the length and width of the image accordingly in the processing step after all the images are captured. Calibrating the  
15 image using knowledge of the time instants at which the vehicle crosses certain pre-determined fixed locations and use these inputs to compute an average velocity over a part of the image for calibration purposes proves convenient.

Consider **figure 5**, which illustrates the same. L1, L2, ... are predetermined locations at which the vehicle's entry and exit time instants would be recorded by the system by employing suitable  
20 sensors like pressure sensors, loop sensors, infra-red sensors, laser or any other kind of sensor which can give a point readout when the vehicle enters a particular location or exits the particular location. The distances between L1, L2, ... are known to the system and time instants at which the vehicle entered/exited the corresponding locations allows the system to compute the average velocity of the vehicle within that time span.

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For example, if  $D(L_i, L_j)$  is the distance between the locations  $L_i$  and  $L_j$  and  $t_i$  and  $t_j$  are time instants at which the vehicle had entered the corresponding locations, then the average velocity within the period  $t_i$  and  $t_j$  is given by .

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$$V_{ij} = D(L_i, L_j) / (t_i - t_j)$$

Using the average velocity of the vehicle between various points and correlating the same to the time instants at which different parts of the vehicle was imaged the the composite image(s) can be calibrated to a standard reference velocity which would normalize the overall length and width of

the composite images for different vehicles. In case of area-scan cameras, image registration among the original images is used to calibrate the composite image.

**Figure 6** shows a calibrated image formed from an uncalibrated image. The image region, marked out by the arrows denoted Li and Lj in the uncalibrated image, is converted to the corresponding image region in the calibrated image.

The working of other modules of the computing system is now described.

Automatic adjustment of the image intensity comes into use because the undersides of vehicles are typically nowhere near flat and comprise various overhangings and cavities and objects at different heights at different parts along the length and width of the vehicle. While the lighting unit provides uniform lighting if the vehicle are being imaged is close to flat, the variations mentioned results in images captured by the cameras to have uneven lighting at different parts of the image, with some parts being very dark or under-exposed while some other parts are very bright or over-exposed. In either of the above cases the details in these parts of the images get lost. In order to compensate for the above variations and compute a resulting image which is globally corrected for proper image intensity and clarity at all parts, the image is divided into logical sub-images as depicted in **figure 7**.

A measure of the local intensity and contrast in each of the sub-images is computed.

The measures for the intensity and contrast in the region are computed. Once the above measures are computed for each of the regions the correction can be applied to these regions by comparing with a configurable preset reference values for the same measures.

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The number of regions that the image is divided into can be configurable. Possible divisions can be regions of size 16x16 or 32x32, etc. The actual size of the regions can be chosen based on the amount of local correction that is required. Smaller regions can result in better globally corrected images, but very small regions result in sudden variations across the boundaries of the regions, very large regions results in the average intensity and contrast of the image getting better but the local outliers like small dark or over-saturated patches would not be corrected. Also the amount of computation power and hence the delay in displaying the processed image vary according to the size of the region selected.

Hence the size of the region is a configurable parameter which can be varied according to the operator needs and convenience. The above method describes a means to globally correct the image for variations that arise due to the presence of under-exposed and over-exposed regions in the same image. Another scenario that happens is the lighting variation that happens due to  
5 different vehicles having different ground clearance. The lighting unit providing less illumination for vehicles having higher ground clearance and more illumination for vehicles having lower ground clearance. This results in images of varying intensities according to the varying ground clearances.

The same technique of image adjustment based on the measures described above can be applied  
10 in this case also without dividing the image into smaller regions. This results in much less computation as opposed to multiple regions. Alternatively if corrections for both kinds of variations need to be performed, the technique above will suffice.

The identification of the make and model by the instant invention includes the system storing  
15 standard images of different makes and models of vehicles in its database. For all images in the database the following measures are computed. The image is divided into various sub-regions as illustrated in **figure 7**. The exact size of the different regions would depend on the level of accuracy that is required in the detection process versus the amount of computation time that be used for doing that. Smaller sized regions would produce better results but would be more time consuming.  
20 Regions of size 32x32 or 48x48 should be good choices, giving very fast results without compromising on the accuracy.

For each of the sub-regions the most prominent features in the region is located. The method for doing this feature detection can be any of the standard feature detection techniques which are  
25 commonly known in the literature as long as they produce consistent and suitably sparse feature detections across various images. For purposes of illustration below we have used a measure provided by Lucas and Kanade Ref: **An Iterative Image Registration Technique with an Application to Stereo Vision (IJCAI)** B.D. Lucas and T. Kanade Proceedings of the 7th International Joint Conference on Artificial Intelligence (IJCAI '81), April, 1981, pp. 674-679.  
30 [http://www.ri.cmu.edu/pubs/pub\\_2548.html](http://www.ri.cmu.edu/pubs/pub_2548.html)

Top few features, which are sparsely located, based on their feature strength are selected and normalized cross-correlation on small windows around the features in the same region on the standard image are performed and thus the top candidate matches are computed.  
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The correct matches for the various features are selected by checking the consistency of the matches using translation as a measure across the different features. a global measure of the match of the current image and the standard image is performed by summing up the correlation measures of the pruned matching features after outlier elimination. Regions whose pruned feature count falls below a certain fraction of the original feature count are eliminated from the global similarity measure.

The standard image having the maximum global similarity and any other images which fall within a certain percentage threshold of the maximum are candidates for make and model match and are displayed to the operator.

Once the vehicle's make and model has been identified by the above method, the current image can be automatically compared with respect to the standard image stored in the database to determine if there are any dissimilarities in the image of the current vehicle. The processes of vehicle make and model identification produces as output a set of feature point matches between the current image and the standard image for each of the sub-regions in the image. Using the feature point matches, the translation parameters can be computed to warp the sub-region of the current image to the corresponding sub-region of the standard image. The computed translation parameters are used to transform the image sub-region to the same frame of reference as the standard image. After performing the transformation, the two image regions can be correlated to get a measure of the similarity of the whole region. Regions whose similarity measure is less than a certain threshold (say 0.9) are flagged as candidates for possible dissimilarities and the regions are marked out in a suitable color and an alarm is raised at the operator console prompting him/her to inspect the region in greater detail.

Smaller sized regions (say of size 48x84 or 64x64) are ideal choices for performing image comparison because they provide a pretty good level of zeroing in on the possible dissimilarity while at the same time not raising too many false alarms.

The instant system also includes computer program product configured to perform the steps described above. The computer program products can run on any electronic device configured to perform the same. The modules described above run with the help of executable computer programs.

**Figure 9** shows such electronic device consisting of various subsystems interconnected with the help of a system bus **(112)**. The microprocessor **(113)** communicates and controls the functioning of other subsystems. Memory **(114)** helps the microprocessor in its functioning by storing instructions and data during its execution. Permanent Storage **(115)** is used to hold the data and instructions permanent in nature like the operating system and other programs. Display adapter **(116)** is used as an interface between the system bus and the display device **(117)**, which is generally a monitor. The network interface **(118)** is used to connect the computer with other computers on a network through wired or wireless means. The computer may also be connected to the internet for providing and downloading relevant lessons. The computer system might also contain a sound card (not shown). The system is connected to various input devices like keyboard **(119)** and mouse **(120)** and output devices like printer **(121)**. Various configurations of these subsystems are possible.

It will readily be appreciated by those skilled in the art that the present invention is not limited to the specific embodiments shown herein. Thus variations may be made within the scope and spirit of the accompanying claims without sacrificing the principal advantages of the invention.

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## **We Claim**

1. A method for network based automatic inspection system for vehicles comprising:

- detecting arrival of a vehicle near said automatic vehicle inspection system by a first sensor in said system, - initiating said system by said sensor,
- detecting location and time instants of said vehicle at predefined and configurable points and providing point readouts at said locations by an array of sensors ;
- capturing images and videos of said vehicle at different view angles as the vehicle moves over the inspection system by a set of cameras at different orientations;
- transmitting said images and videos, detected location and time instants to a computing means;
- processing captured images using said time instants and detected locations;
- calibrating captured image(s) using multiple sensors,;
- automatically adjusting captured image(s) using local brightness and contrast measures in image sub-regions for improving the visual clarity of the processed image;
- automatically detecting the make and model of the vehicle using process (es) of feature detection, correlation, outlier-rejection and global similarity measure;
- automatically comparing captured images with images stored in a database for region dissimilarity detection in the vehicle underside using sub-region warping, correlation and global similarity measures;
- detecting exit of vehicle from the inspection system and deactivating said vehicle inspection system by a second sensor and
- displaying, inspecting and storing said processed images, on-demand analyzing a user defined portion of composite image.

2. The method as claimed in claim 1 wherein a combination of line scan images and videos are used to provide interactive inspection of vehicles.

3. The method as claimed in claim 1 wherein the sensors are selected from a group comprising of induction loops, pressure sensors, proximity sensors, sonar or ultrasound sensors, laser rangefinders and infra-red sensors.

4. The method as claimed in claim 1, wherein super-resolution techniques are applied to captured videos in order to improve their resolution.

5. The method as claimed in claim 1, wherein videos are processed to form separate mosaics, the mosaics covering the entire length of the vehicle, the width being according to the view of the image capturing means.
6. The method as claimed in claims from 1 to 5, wherein intensity adjustment means is provided, the intensity adjustment means being configurable to take care of varying ground clearance of different vehicles.
7. The method as claimed in claim 1, wherein said method comprises the step of capturing images of license plate and occupants of the vehicle.
8. The method as claimed in claim 1, wherein said method comprises the step of converting license plate number image to machine readable alpha-numeric format.
9. A system for network based automatic inspection of vehicles, comprising
  - a first sensor for detecting arrival of a vehicle near said inspection system and initiating the inspection system,
  - a second sensor for detecting exit of vehicle and deactivating said system,
  - a sensor array for detecting location and time instants of the vehicle at predefined points,
  - a combination of linescan camera and/or area-scan camera (for capturing composite image) and area-scan cameras (for capturing videos of the vehicle underside), the second set of cameras being positioned and oriented at strategic locations and angles to capture regions not visible in composite image for enhanced inspection.
  - processing means for processing images captured by image capturing means using said detected location, the processing means configured for calibrating captured image(s) using multiple sensors and for automatically adjusting captured image(s) using local brightness and contrast measures in image sub-regions;
  - means for automatically detecting make and model of the vehicle using process(es) of feature detection, correlation, outlier-rejection and global similarity measure
  - means for automatically comparing captured images with images stored in a database for region dissimilarity detection in the vehicle underside using sub-region warping, correlation and global similarity measures
  - means for displaying, inspecting and storing said images, and analyzing a user defined portion of processed images and videos.
10. The system as claimed in claim 9, wherein said inspection system comprises a light and mirror assembly.

11. The system as claimed in claim 10, wherein said light and mirror assembly comprises:

- a reflecting mirror, arranged at appropriate angle, for viewing lighted area of the vehicle, a reflective sheath for the light and,
- diffusion means to optimally adjust quality and quantity of light.

12. The system as claimed in claim 11, wherein said image capturing means comprise: - an array of linescan or areascan cameras adapted to capture partial (overlapping) images of the underside of vehicles for higher resolution imagery,

13. The system as claimed in claim 9, wherein said processing means comprises: Input and display means, means for communicating with the vehicle inspection system, and means for storing videos and images forwarded by vehicle inspection system, and intelligent processing means for comparing captured images with stored images for vehicle make and model detection using feature detection, correlation and region dissimilarity detection using sub-region warping and correlation.

14. The system as claimed in claim 13, wherein input means comprises touch panel, voice recognition and handwriting recognition for user interaction.