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Image Processing in Automotive Industry: Research Paper

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Abstract: *Under this very research paper I would be documenting the role that image processing plays in the automotive sector. And also how image processing is put to use in this very industry where accuracy is what matters the most i.e. how, where and why image processing is used in the automotive industry.*

Keywords: Digital Image Processing, Automotive Industry, Computer Vision, Pixels, Images, LiDaR, Driver, Vehicles

I. Introduction

An image can be defined as a two-dimensional function F(x,y) wherein x and y are spatial coordinates and the amplitude of the function F at any pair of coordinates (x, y) is called the intensity of that image in particular, at a given point. When the x, y and amplitude values of F are all finite, that is when we call it a digital image.[1]

Every image that we see is made up of a finite number of elements that work in harmony. Each of these elements have a specific value at a specific position. These elements are usually referred to as picture elements, image elements and pixels out of which, the pixel is most widely used to denote the elements that a digital image comprises.[1]

1.1 Types of an Image

Here are the few types of an image that we have come across so far:

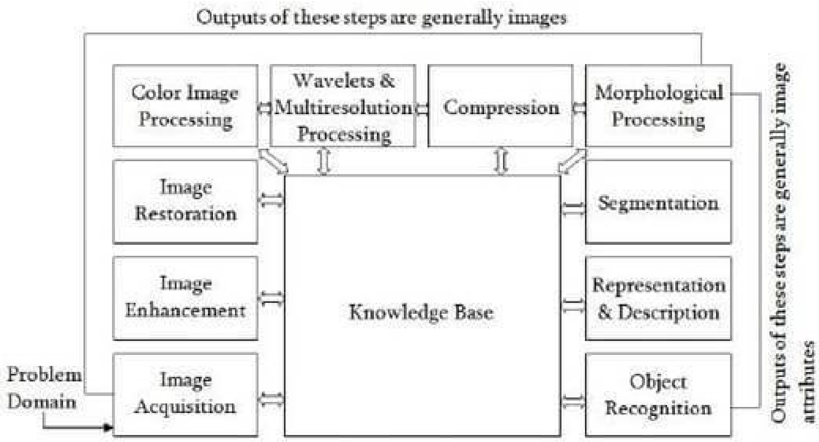
1. **Binary image:** It is an image that has only 2 pixel values - 0 and 1. Wherein 0 represents black colour while 1 denotes white colour. Such an image that is black and white is also known as a Monochrome. The gray level is absent in such images as black and white are the only 2 colours that can be found in a Monochrome.[1]
2. **Black and White image:** A black and white image can be considered as a binary image as the image consists of just 2 colours–black and white.[1]
3. **8-bit colour format:** Considered as the most famous image format, this type of image consists of 256 different shades of color. It's commonly known as grayscale image wherein 0 represents black color, 255 represents white color and 127 represents gray color.[1]
4. **16-bit colour format:** It's a color image format that has 65,536 different colors in it. It's actually of high-colour format as the distribution of colours here is not similar to that of a grayscale image.[1]

II. Digital Image Processing (DIP)

Processing a digital image with the help of a computer system is what digital image processing is all about. It can also be considered that certain computer algorithms are used to enhance an image in order to extract some kind of useful information. Here, are a few reasons why, we practice digital image processing:

1. Image Visualization: Used for, observing the objects that are not usually that visible in a given image.[2]
2. Image Sharpening and Restoration: It is used for enhancing the resolution of the image thereby reviving the beauty of it.[2]
3. Image Retrieval: It is used to obtain the image of interest.[2]
4. Measurement of Patterns: It is used to tag or recognise all the objects that are present in an image.[2]
5. Image Recognition: It is used to not only identify but also distinguish each and every object that is present in an image.[2]

III. Fundamental Stages of Digital Image Processing



1. **Image Acquisition:** It is the very first stage of digital image processing in which an image is being provided to us in the digital form. Additionally, the pre-processing like scaling is also done under this very initial stage of Image Acquisition.[2]
2. **Image Enhancement:** It happens to be the simplest and most attractive stage in the Digital Image Processing (DIP). Under this very stage of Digital Image Processing, certain interesting features of an image are highlighted like Contrast and Brightness for instance.[2]
3. **Image Restoration:** As the name suggests, Image Restoration focuses on restoring the quality of an image. If the image in particular has some defects like noise, motion blur, etcetera then this stage ensures that image is free from all defects by literally repairing the image.[2]
4. **Colour Image Processing:** As colour is a powerful descriptor that simplifies object's identification and extraction, an abstract mathematical model of colour space is used in order to define colours in terms of intensity values. Furthermore, this stage consists of 2 more sub-stages of Pseudo-colour Processing and Full-colour Processing. So in Pseudo-colour Processing, (false) colours are assigned to a monochrome image and whereas in Full-colour Processing, images are acquired with full-color sensors/cameras.[2]
5. **Wavelets and Multi-resolution Processing:** Under this stage, any given image is represented in various degrees of resolution. And also the image is subdivided into smaller regions for data compression and also for the pyramidal representation–wherein image and signal processing technique is used to represent a single image, using a set of cascading images.[2]
6. **Compression:** It is a technique wherein certain pixels of an image are merged together in order to decrease the resolution of an image. This is a very crucial stage as it helps us reduce the number of requirements for storing an image.[2]
7. **Morphological Processing:** It deals with the tools that are liable for extracting the components of the image. It sure is useful for representation and description of the shape.[2]
8. **Segmentation:** In this stage, an image is subdivided into its objects. And it is considered to be the most difficult task in Digital Image Processing as it takes a lot of time for finding a successful solution to the imaging problems that requires objects to be identified individually.[2]
9. **Representation and Description:** This stage relies upon the output that was generated/obtained in the previous stage of: Segmentation. The output is a raw pixel data which has all the points of the region itself. Representation happens to be the only solution for transforming the raw data. On the other hand, Description is used for extracting information to differentiate one class of objects from another.[2]
10. **Object Recognition:** Here a label is assigned to each and every object which is based on the descriptor.[2]
11. **Knowledge Base:** The very final stage of DIP is Knowledge wherein the important information about the image is located that also limits the searching processes. The Knowledge Base turns out to be very complex when the image database has a high-resolution satellite.[2]

IV. Role Of Digital Image Processing In Automotive Industry

LiDaR Technology: Light Detection and Ranging is what LiDaR stands for. This laser-based technology has enabled cars to drive all by itself without the need of a driver. LiDaR maps the surroundings of the car in 3-dimension just like the Sonar does. It's capable of detecting certain objects, variations in the elevation, etc. While the car is being driven all by itself using LiDaR, if it detects any of the things mentioned while mapping the car's surroundings then it'll immediately apply the brakes for us thereby avoiding a possible collision.[4]

However, LiDaR isn't really all that reliable after all as, after rigorous testing it was observed that, the LiDaR could only detect something once the light that was casted upon the object reflects back to the sensor in order to react accordingly. Tesla's CEO, Elon Musk has suggested to focus primarily on the inclusion of cameras and Artificial Intelligence (AI) for the betterment of the LiDaR technology.[4]

Computer Vision (CV): This consists of a set of algorithms that would go out of their way to mimic the understanding of the surroundings just like the way we humans do. It has made possible the use of image recognition in multiple areas. Firstly, the processing unit of CV's identifies the objects with the Machine Learning algorithm (typically a convolutional network) which has been trained on millions of images from the real-life environment. The CV then assigns tags to each object like 'a car', 'a truck' after which it determines their geometric boundaries.[4]

Now, the problem here is that the convolution network could only classify a single image at a time. But, this problem has already been addressed by moving a sliding window over the image and breaking down the image into smaller parts. Meaning that, the image gets splitted into a grid and therefore each part of the grid scores regarding the object it holds.[4]

Computer Vision has itself made it possible for most of the driver assists to work in harmony thereby increasing safety. CV itself has given birth to the major components that are held accountable for the safety of not only the driver but also the other occupants that are riding along with the driver. Those contributing-components, worth mentioning are as follows:

Lane-departure warning (LDW): By making use of various cameras and sensors, the system identifies another vehicle entering the lane without proper preparation (turn signals or ensuring that the road ahead is clear) and warns the driver or even deploys the automated braking systems thereby avoiding a possible collision.[4]

Adaptive Cruise Control (ACC): It allows us to maintain a chosen velocity and distance between our vehicle and the vehicle that is ahead of us. It could also apply brakes or accelerate automatically in order to maintain the distance from the vehicle we are driving behind. The system also demands the driver to be alert at all times as it only governs the acceleration and braking but not the steering.[3]

Automatic Parking: Takes control over the parking functions that includes steering, accelerator and brakes thereby assisting the driver while parking the vehicle in the available parking spot. The system carefully positions itself into the parking space that the driver had the volition for. However the driver must be willing to look after the vehicle's surroundings and take control of the vehicle, when necessary.[3]

Automotive Navigation Systems: For this the drivers seek assistance from the digital mapping tool like GPS (Global Positioning Systems) and Traffic Message Channel (TMC) as they would provide them up-to-date and real-time information about the traffic conditions and also the navigation information. There's an embedded receiver present inside the vehicle that communicates with the satellites regarding the current location of the vehicle.[3]

Night Vision: It enables the vehicle to detect pedestrians, objects, etcetera at night when it's pitch dark and the visibility is hence low. The Night Vision system makes use of infrared sensors, GPS, LiDaR, and Radar so that it can detect pedestrians and objects that the driver couldn't just see at night.[3]

Traffic Sign Recognition: The TSR or Traffic Sign Recognition systems can recognise common traffic signs like the "Stop"sign or "Turn ahead" sign with the aid of Image Processing techniques themselves. The system scans and classifies the shape, type and colour of the sign that is communicating with the driver. Nevertheless, as this system mostly relies and functions with the assistance of cameras we can't fully rely upon them as that renders them less-accurate. It is so because sometimes the system fails to detect the sign when: the weather is not good enough, when the sign is partially visible and also when the sign isn't well lit.[3]

Omniview Technology: It provides a 360-degree surround view and it also provides intricate peripheral images of the vehicle's surroundings to us via the infotainment screen. Currently, the commercial systems offer only 2D images of the vehicle's surroundings. Whereas Omniview Technology uses 4 cameras and bird's eye viewing technology that provides a composite 3D model view of the surroundings.[3]

V. Conclusion

Image Processing techniques have really proved to be beneficial under the automotive industry. Only time will tell how effective DIP is for vehicles. Safety is the topmost concern of the drivers when it comes to relying upon the Image Processing techniques. Despite all the shortcomings, DIP does have a huge scope in the automotive industry as we are inching closer to a driverless future with self-driving autonomous cars.

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