Advanced Trustworthy Tire System

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Abstract

Damage tire can cause loss of traction which may lead to rollover of the vehicle. In order to avoid such situations several systems have been proposed; however, the accidents continue although their number has been reduced. We would like to add our contribution to this field that will make the current systems even more reliable and trustworthy.

I. INTRODUCTION

Scratched tires are the key reason for rollover car accidents [1]. Rollover crashes are just 2% of the crashes in US, but 33% of the occupant fatalities are caused because of rollover crashes; this means more than 10,000 occupant fatalities each year only in the US because of damaged tires [2].

These worrisome numbers motivated researchers to find ways to find ways to detect below standard tires. Some of them used special equipment like eyefish lens [3] or a complex intelligent wireless sensor network inside the tire [4,5,6].

Some works aim at simulating accidents and estimate the potential damage [7]. This is not the aim of this work. Our work aims at detecting a potential exposition to danger and notify about it.

We suggest using an ordinary digital camera to find below standard tires. Nearly all digital cameras can produce JPEG pictures. JPEG is a very common method for image compression and it is also extensively used by electronic devices like scanners and digital cameras [8].

JPEG images have many advantages the straightforwardness of adaptation for new compression methods [9] and the capability of flexible implementation for hardware from different vendors [10].

Images are often stored in a compressed standard. A naive approach for image processing on compressed images would be to decompress the image and then running the image processing algorithm on the original image data. Instead, for some image operations, we can act on the compressed data directly. This gives us two benefits: first, we can use the standard digital cameras without a need to adjust the digital camera; second, we can use the frequency information embedded in the compressed data.

The rest of the paper is organized as follow: section II describes the JPEG compression standard.

Section III explains how JPEG can be used for detecting damaged tires, section IV gives some results and section V concludes the paper.

II. THE JPEG STANDARD

JPEG is a well known standardized image compression technique. JPEG loses information, so the decompressed picture is not the same as the original one. By adjusting the compression parameters, the degree of loss can be adjusted. The wide use of JPEG is because of two fundamental reasons: reducing the size of image files, and storing full color information.

Reducing image files will be an important procedure when we transmit files across networks or when we archive libraries. Usually, JPEG can remove the less important data before the compression; hence JPEG will be able to compress images meaningfully, which produces a huge difference in the transmission time and the disk space.

The second advantage of JPEG is the capability of storing full color information: 24 bits/pixel or 16 million colors, while for example the GIF format, can store only 8 bits/pixel or 256 colors.

Here is a brief overview of the JPEG algorithm:

The first step transforms the image color into a suitable color space. There are several methods to transform the image into a color space [11,12]. The most common methods are the split into RGB components [13] or the split into YUV components [14]. These components are interleaved together within the compressed data. The ratio between these components is usually not one to one. When YUV components are used, usually the Y component will have a four times weight. The human eye is less sensitive to the frequency of chrominance information than to the frequency of luminance information which is represented by the Y component in the YUV format. Hence, the Y component gets a higher weight [15].

The second step groups the pixels into blocks of 8X8 pixels. Then, it transforms each block through a Forward Discrete Cosine Transform (FDCT) [16]. The DCT gives a frequency map, with 8X8 or 64 elements. The transformation keeps the low frequency information which a human eye is sensitive to. In each block the DCT coefficients are composed of: A single Direct Current (DC) coefficient number, which represents the average intensity level value in each block and the remaining 63 are named Alternating Current (AC) coefficients. They reflect the frequency information of their row and column.

The next step is the quantization. The 63 AC coefficients are ordered into a zig-zag sequence which arranges them into a one dimensional array. In each block, each of the 64 frequency components is divided by a separate "quantization coefficient". The quantization coefficients are set according to the desired image quality. The results of the division are rounded to integers. This step loses some information because of the rounding. Furthermore, it can be noted that even if the quantization coefficient is 1, some information will be lost, because typically the DCT coefficients are real numbers.

The last step encodes the reduced coefficients using either Huffman or Arithmetic coding. Usually a strong correlation appears between DC coefficients of adjacent 8X8 blocks. Therefore, JPEG encodes the difference between each pair of adjacent DC coefficient. Baseline JPEG model uses two different Huffman trees to encode the data, one for the DC coefficients' length and the other for the AC coefficients' length.

Finally, the compression parameters are written in the file header, so that the decoder module will be able to decode the compressed image. JPEG's procedure is summarized in Figure 1.

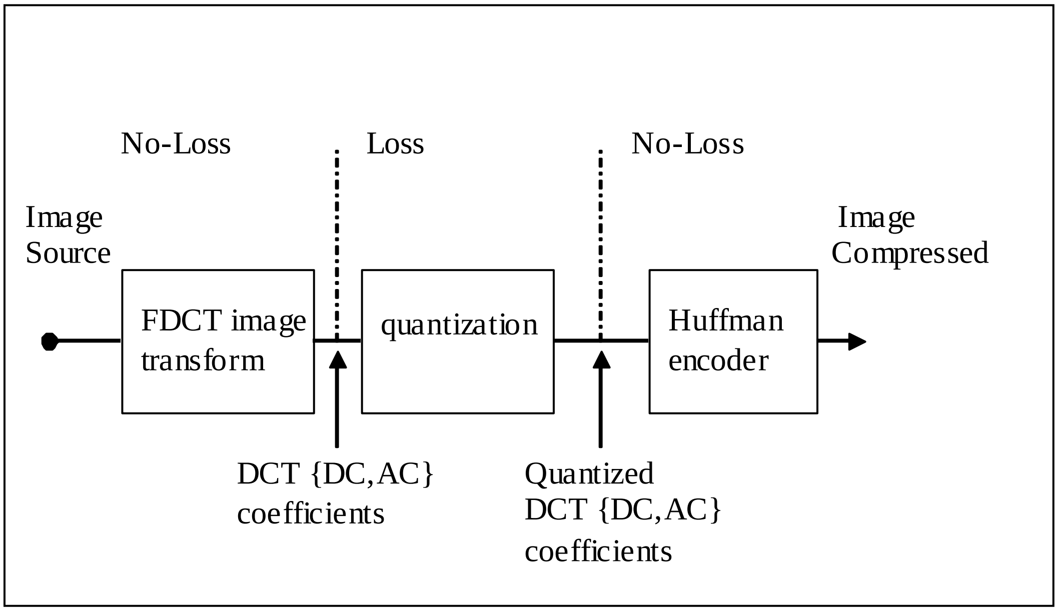


Figure 1: JPEG Model for a lossy image compression

The decompression process performs an inverse procedure:

- It decompresses the Huffman or the Arithmetic codes.
- Then, it makes the inversion of the Quantization step. In this stage, the decoder raises the small numbers by a multiplication of them by the quantization coefficients. The results are not accurate, but they are close to the original numbers of the DCT coefficients.
- Finally, an Inverse Discrete Cosine Transform (IDCT) is performed on the data received from the previous step.

JPEG has some disadvantages. Unfortunately, even with a JPEG viewer, it takes a longer time to decode and view a JPEG image than to view an image of a simpler format such as GIF, BMP, etc.; however it is still a very short time as can be indicated in every digital camera. Another disadvantage is the compression method that does not take into account the temporal correlation of the coefficients.

III. Using JPEG for damaged tire Detection

This section describes the Damage Tired Detection algorithm using the JPEG format. As mentioned above the JPEG standard is based on the DCT paradigm. The DCT changes the picture into frequency space. The frequency coefficients, which are very low magnitude, are rounded to zero. When most of the coefficients in a block are zero or very low magnitude: The compression algorithm will give a very short bits sequence for such a block. Zero sequences are treated very efficiently by JPEG compression and the results will be only few bytes.

When there is a drastic change in a block of 8X8, the value of many frequency coefficients will be high. Such a sequence will be compressed into many more bits. JPEG’s standard stipulates that the block’s size will be 8X8 pixels, but the algorithm will be obviously good for other small NXN pixels size too.

When looking for the contour of an object, the goal will be to find the object's border. The idea is to break the compressed file into its original blocks, then look in the compressed file for long bit sequences. The blocks which are compressed into long bit sequences, are presumed to be the object's border. In our implementation we took a simpler approach. We take many pictures of each tire. We actually take a close picture of each part of the tire. If the entire size of a picture is above a certain threshold, we will consider this part of the tire as a damaged part.

If we have no idea what the threshold value should be, we can examine the probability density function (PDF) of the block representation to select a suitable value. In the uncomplicated case the PDF should be mono-modal and we set the value in the inflection point.

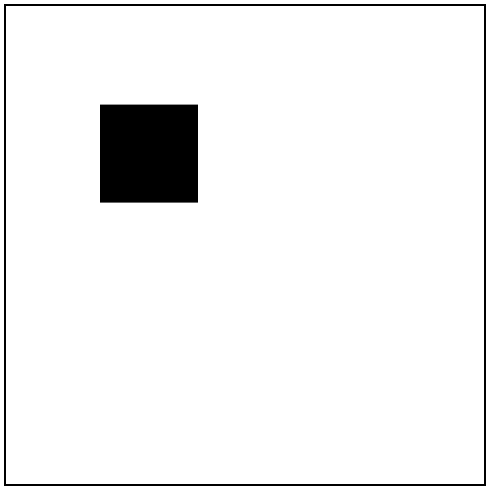
Many pictures are taken by rolling the tire and in each picture suspected objects are searched.

Note the method does not use the spatial information in the blocks, so it would identify any sequence of bits as a contour of the object, which is a weakness of the algorithm. Our assumption is that the resolution is large enough to describe the shape's character.

JPEG format of uniform area

0	0	1	0	1	0

Original image



JPEG format of the upper left corner of the black square

-12	18	-8	-2	3	-1	-1	1
22	-25	8	2	-3	0	1	-1
-18	20	-7	-2	2	0	-1	1
16	14	4	1	-1	0	1	1
-11	10	-2	-1	0	-1	-1	0
6	-5	1	-3	0	0	0	0
-2	2	-1	0	0	0	0	0
1	-1	0	0	0	0	0	0

Figure 2. A sample image and how JPEG can be used for contouring

Figure 2 demonstrates how JPEG is used for contour extraction. The original image was compressed in grayscale baseline JPEG format with 75% quality. The left image shows the original image, which is a high-resolution picture of 1000X1000 pixels. The upper-right image shows the JPEG format in the white or black area. The lower-right image shows the JPEG format in the upper left corner of the black square. The size of the black square is 200X200 pixels and the square is not aligned relative to JPEG’s 8X8 blocks.

The JPEG file reports the difference of magnitude between the DC’s coefficients of a previous block relative to the current block. In the case of a white or black area there are no changes in the coefficients’ magnitudes. This type of block is encoded as six bits by the JPEG standard [7].

The output of the JPEG file is shown in Figure 2. The “00” reflects that there are no differences between the values of the previous and the current block’s DC coefficients, and “1010” symbolizes the end of the block. If there is a difference between the intensity of the DC coefficients of the previous and the current blocks, the size of the encoding block will be slightly bigger. For example, a block which encodes a sharp change from white to black is represented by a wide range of frequency coefficients. It is easy to select a threshold that delimits the edges of the shape from the rest of the image.

Figure 2 shows a sample of the block, which contains the upper left corner of the black square. In order to compress these values in JPEG standard, 243 bits are needed. The difference between 6 to 243 is obviously significant. By using three parameters the length of the block, its magnitude and the number of consecutive blocks the threshold can extract the contour with a range of scalar values [17,18]. The extra parameters allow more control over the resulting mechanism.

IV. Results

We examined our technique on some hundreds of tires and succeeded to find some damaged tires. Clearly, obvious cases like in Figure 2 do not exist in real tires, but we still succeed to find most of the damaged tires by rolling the tire and take many picture of it in all of its parts.

Figure 3a. Damaged Tire

Figure 3b. Damaged Tire

Figure 3c. Damaged Tire

We used an Olympus FE-170 digital camera. The Images with no damage in the tire produced images in size of less than 1.3MB; whereas images in size of more than 1.5MB usually had damage in the tire.

Figures 3a, 3b and 3c show some damaged tires that our system has found. All of these pictures were on vehicles of volunteers. Driving a vehicle with such damages can be a substantial risk of life!

The images between 1.3MB-1.5MB sometimes had a small scratch and sometimes it was only a change in the color shade. Also the caption on the tire can increase the size of the image; however, the caption typically increases the image size less than the increase that a real damage makes; however, it may make the size above 1.3MB.

Figure 4a. Tire with a Change in the Color Shade

Figure 4b. Tire with a Change in the Color Shade

Figures 4a and 4b show two cases where a change in the color shade of the tire made the result above the threshold of 1.3MB and caused an uncertain result.

Figure 5. Dirt on the Tire.

There are also cases where our system has produced false alarms. Figure 5 shows an example for such a false alarm. The dirt on the tire in Figure 5 can be easily noticed. This dirt made the system assuming that the tire is damaged; whereas this tire was undamaged and the vehicle was safe for driving.

Therefore, we recommend washing the tire before the system tests the vehicle. Dust, dove feces, mud and any other dirt can mislead the system, especially if the dirt is white.

V. Conclusions and Future Work

Rollover accidents are very dangerous and cause too many loss of life. Since most of the rollover accidents are a result of damaged tires, the keeping of the tire in a good shape is more than important. Although there are reports arguing that the human factor is the main reason for rollover accidents [19], we would not advise any driver to pay no attention to the shape of his tires.

In this paper, we explained how a system using simple equipment – digital camera can detect damages in a tire. In the future we would like to adapt our system to a moving vehicle. Conventional digital cameras cannot take a picture of so fast moving object, so we should find a practical way how the pictures can be taken. A possible solution might be taking the pictures when the vehicle moves slowly before or after stopping.

With the ability to detect tire damage before an accident, this simple device can be a lifesaver. This simple device is a valuable addition to any vehicle, as it can help to keep drivers safe by detecting tire damage before it causes an accident.

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