Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2008, 4 (1), 39 - 43

Moiré Aided Soil-Tractor Tire Contact Area and Contact Volume Determination

Fernando KUNINARI, Inacio Maria DAL FABBRO, Antônio Carlos Loureiro LINO
Celina de ALMEIDA
Campinas State University, Faculty of Agricultural Engineering,13083970, Campinas, Brazil.
inacio@agr.unicamp.br

Abstract: This research work reports the application of a phase shift moiré technique in obtaining soil – tractor tire contact area and contact volume. The experimental setup included a multimedia device, a PC, a tractor tire and the following software for image processing: ImageJ, Rising Sun Moiré, IDEA and Scilab. First, a tractor tire was pressed onto a soil surface to produce a "foot print". Four digital grids, out of phase one from each other by π/2 and denoted by G1, G2, G3 and G4, were projected flat white opaque reference surface, having these image photographed by P1, P2, P3 and P4, respectively. Following, the grid G1 was projected onto tire "foot print", generating the image O1. Images Pi and image O1 were converted to gray gradient by means of the software ImageJ. The difference between images O1 and Pi generated four images Mi which were filtered by the RisingSun Moire and IDEA softwares, yielding the "foot print" images topography in gray gradient as well as in moiré fringes. The ImageJ software filtration process applies the Gaussian Blur method to eliminate the original grid, preventing, that way, undesirable interferences. A binary mask of the "foot print" was created and a correction factor between the real image scale and the moiré image scale was obtained to calculate the tire-soil contact area as well as the contact volume. The paper conclusions are direct to the simplicity as well as the significance of the proposed method.
Key words: soil-tire contact area, soil-tire contact volume, moiré technique.

INTRODUCTION and LITERATURE REVIEW

Soil compaction is considered an important problem for the mechanized agricultural systems. So, the identification of soil compacting sources can be an important means to forward the problem solution. Great part of Brazilian tractors are equipped with tires which are known to cause compaction. The phenomenon is generated when screens of certain mesh density are superposed, producing wave like patterns or fringes, which move when its relative positions are displaced (Sciammarella, 1982).The measurement of this parameter will give the level of injuries caused by the transportation of the fruits. Tractor traction performance can be considered a multifactor problem in which inflating pressure, tire geometry and material properties, soil class and physical conditions as well as agricultural operation mechanical demands play significant rules. Soil-tire contact area is particularly important to the tire elastic deformation, soil penetration resistance to tire profiles and slippage. The pertinent literature discloses several approaches to determine contact area regarding tire performance, which include Hertz contact stress theory and applications. The moiré phenomenon is observed when screens of certain mesh density are superposed, producing wave like patterns or fringes, which move when its relative positions are displaced (Sciammarella, 1982). A new technique named "phase shifting" is proposed, which can be seeing as a variation of the moiré methods. A conventional moiré setup has been employed which included a multimedia projector, a digital camera and a data acquisition system. A number of four out of phase sinusoidal fringes, respectively by □/4 radians one from each other were projected onto the soil surface after tire printing. Soil surface had previously pulverized with white color to improve contrast. Tests were carried out during the night to avoid light interference. The technical procedure included image subtraction by means of the ImageJ program, followed by a binary mask application and, sequentially packing and finally, the unpacking procedure carried out by means of the ®Rising Sun Moiré software, generating the final topographic view of the soil-tire contact area represented in gray levels. The software named ImageJ is quite popular in medical research and practices, which was written to recognize area, volume, topography, among other parameters. That software is written in JAVA and it is multi-platform, compatible with Windows, Linux and MAC/OS. ImageJ also offers open source programs with many algorithms applicable to several image archives format, to detect boundaries, image sharpness, areas, average and centroid determination, as well as morphological operations. The objective of this research work is to study the application an optical moiré technique to generate a qualitative soil compaction map, under static loads applied by tractor tires.

MATERIAL and METHOD

The experimental part of this research work was carried out at the Farm Machinery Laboratories of the Agronomic Institute of Campinas, in Jundiaí, SP, Brazil. The testing setup included a multimedia device, a PC, a tractor tire and the following software for image processing: ImageJ, Rising Sun Moiré, IDEA and Scilab. First, a tractor tire was pressed onto a soil surface to produce a "foot print". Figure 01 illustrates the selected setup. The methodology follows the following steps. A small rubber cube was employed to generate a corresponding scale of image and real distances.

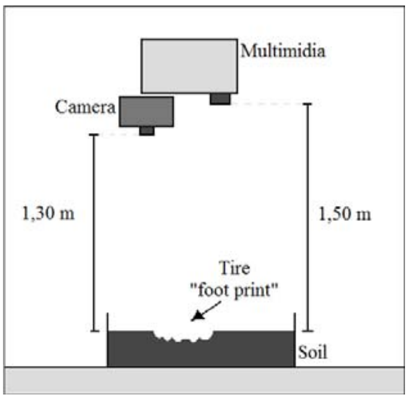

Figure 1. Details of the selected experimental setup.

Step 1 - recording cube image and tire "foot print" on the soil without grid to generate the mask (a) and with the first grid to generate moiré fringes. Recording the images of each one of the projected out of phase grid onto the white background.

Step 2 - application of the software ImageJ to create the mask on the images corresponding to the cube, to the soil only and to the "foot print". Pixel of value equal to 1 corresponding to the cube and to the "foot print" images and 0 value to the soil background surface. Calculate the difference between the object image generated from the first grid projection and the 04 images generated from the 04 out of phase grid projection onto the white background. Applying the ImageJ software for the Gaussian blur filtration process corresponding to the all the images obtained from each out of phase grid projection, including the cube, the soil, the "foot print". Multiplying the resulting images by the mask to exclude the soil background.

Step 3 - applying the IDEA software to pack the 04 images in a single image, generating the packed phase. To unpack the image by means of the same software to generate the gray gradient topographic image.

Step 4 – forwarding the image generated by the IDEA software, as mentioned above, to the Rising Sun software to generate a three dimensional image.

Step 5 - forwarding the image to the Scilab software to obtain its matrix reprentation by means of plugins. To subtract the soil background image from the total image, obtaining only the tire "foot print" image. The generated matrix will exhibit the X and Y values to represent the horizontal dimensions and Z value presented in gray scale.

Step 6 – calculating tire "foot print" area and volume. Fiding the real are contained in 1 pixel by comparison with the cube area image. The total cube area is represented in a certain number of pixels. To sum the Z values of all pixels and multiply it by the area indicated by each pixel. A Z values is proportional to one real distance dimension.

RESULTS and DISCUSSIONS

Figure 02 shows the cube image with projected grid and Figure 03 shows the tire "foot print" image without grid (a) as well as the tire "foot print" image with grid (b) and soil background image without grid (c) together with soil background image with grid (d). Figure 04 displays the cube mask (a) and tire "foot print" mask meanwhile Figure 05 exhibits he resulting subtraction between white background images and tire “foot print” images. Figure 06 shows the soil background images with grids after the filtering process and Figure 07 shows the tire “foot print” images with grids after filtering process and Figure 08 displays the soil background and tire “foot print” images with grids after multiplication by the mask. Figure 09 shows the contour lines on the soil background (a) and on tire “foot print” (b) and Figure 10 shows tire “foot print” expressed in gray gradient topographic image. Figure 11 shows the final expression for the tire “foot print” in three dimensional image. The final results are summarized by Figure 09, Figure 10 and Figure 11, which, by the quality as well as the amount of information, justify the present research work. However, it should be emphasized that the experimental part of this work was carried in field conditions. Future work should consider the development the proposed technique in laboratory conditions keeping close control on influencing factors.

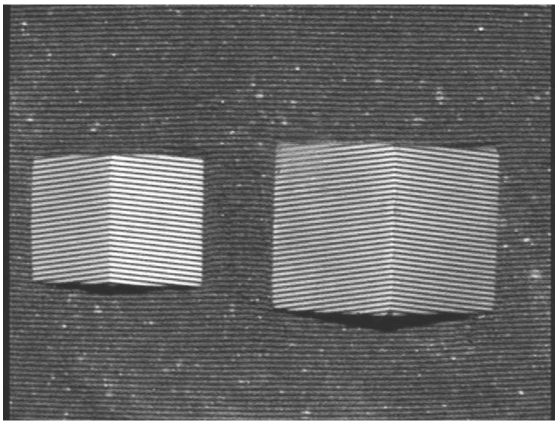

Figure 2. Cube image with projected grid.

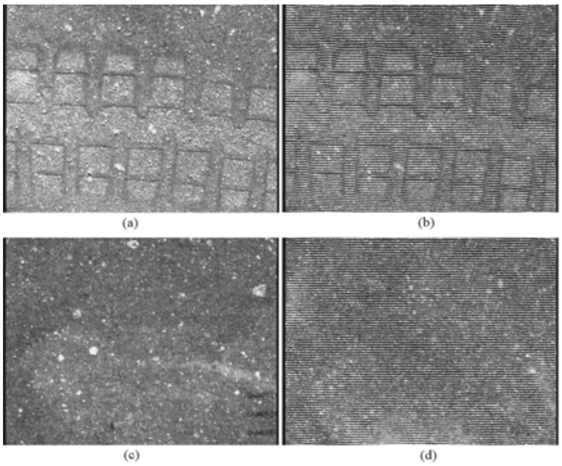

Figure 3. Tire “foot print” image without grid (a), tire “foot print” image with grid (b), soil background image without grid (c) and soil background image with grid (d).

Figure 4. Cube mask (a) and tire “foot print” mask.

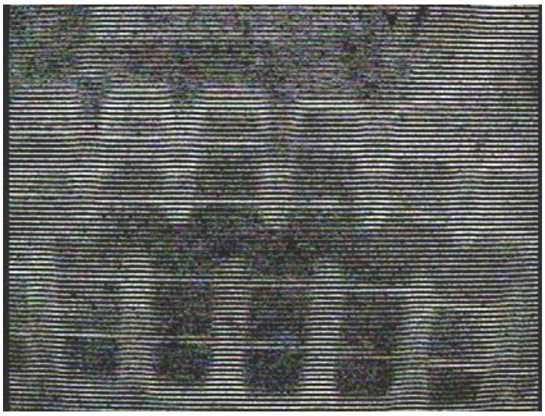

Figure 5. Resulting subtraction between white background images and tire “foot print” images.

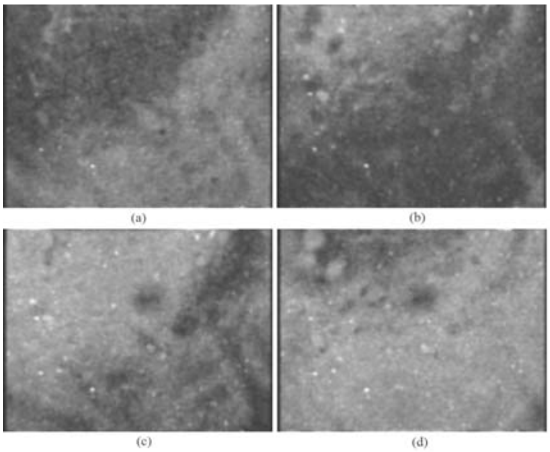

Figure 6. Soil background images with grids, after filtering process.

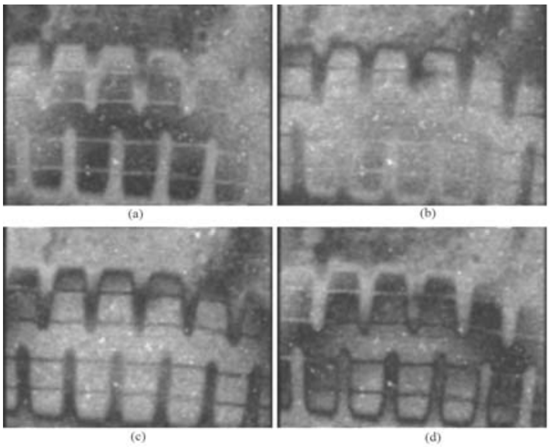

Figure 7. Tire “foot print” images, with grids, after filtering process.

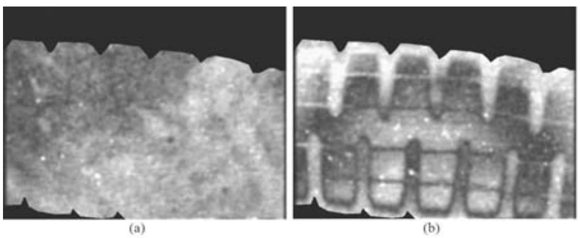

Figure 8. Soil background and tire “foot print” images, with grids, after multiplication by the mask.

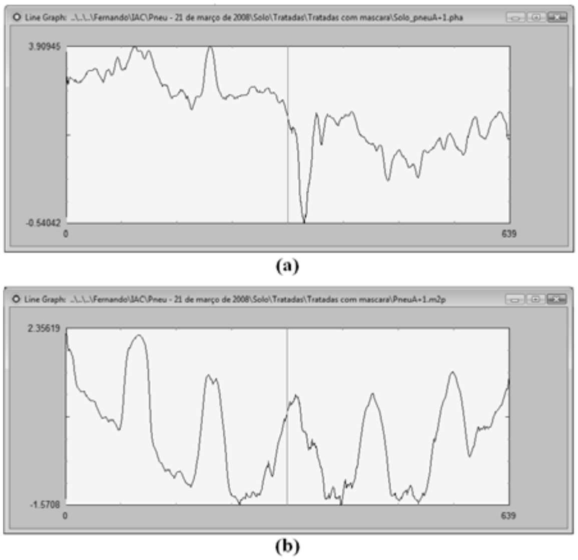

Figure 9. Contour lines on the soil background (a) and on tire “foot print” (b).

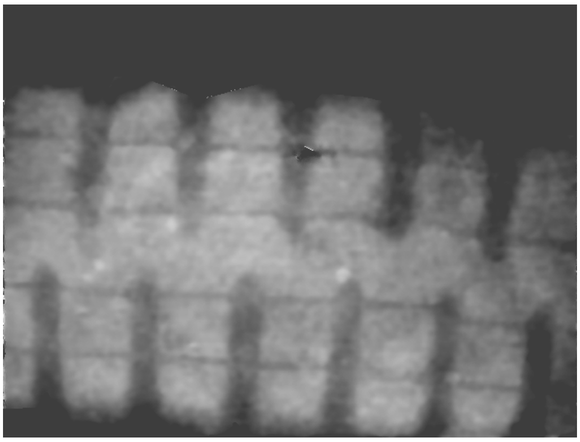

Figure 10. Tire “foot print” gray gradient topographic image.

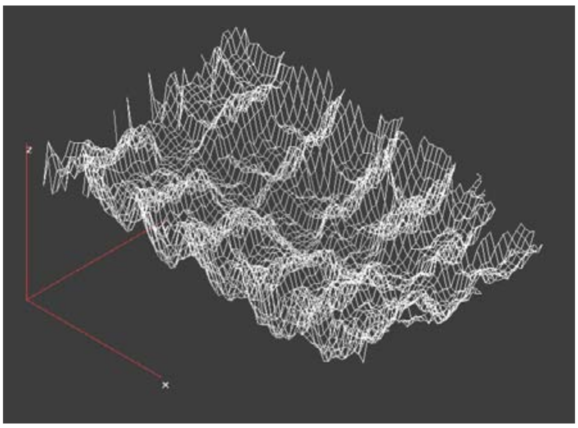

Figure 11. Tire “foot print” three dimensional image.

CONCLUSIONS

Based on what it has been exposed before, final conclusions can be summarized as follows. The propose technique offers no major difficulties in data generation as well as on data processing. However, the applied softwares could be adapted to the particular situation, optimizing testing timing. Future works should consider the application of tests in laboratory conditions to keep the interacting factors under close control.

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