REGISTRATION SOFTWARE FOR TWO-DIMENSIONAL EXPERIMENTS PERFORMED ON AN AIR SUSPENSION TABLE

SOFTWARE DE REGISTRO PARA EXPERIMENTOS BIDIMENSIONALES REALIZADOS EN UNA MESA DE SUSPENSIÓN DE AIRE

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Abstract: This work is aimed to document the replacement the expensive registering metallized paper used by the table with air cushion Leybold Didactic GMBH to record the movement and collisions of two particles on a two dimensional surface. Those experiments use two cylinders that move on the table with minimal friction due to air cushion produced by themselves, which allows them to move almost without friction on the glass surface. The research work involves the design of image processing software in which an algorithm has to acquire, process and record the trajectory of two cylinders that move on the table with minimal friction is developed. For implement this, a study of the experiments carried out on the table and displayed on the registering metallized paper is made. Based on the results this digital tool is design to replace the paper and allow the academic community to use this table sustainably and without relying on costly inputs. Additionally it was analyzed the error obtained due to the pass of images through the algorithm, resulting just a 3% of total error than respect to using real paper.

Keywords: 2D particle collision, air cushion, image processing, thresholding.

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Resumen: El presente trabajo tiene como objetivo documentar la sustitución del costoso papel metálico utilizado por la mesa con el cojín de aire Leybold Didactic GMBH – donde se registra el movimiento y las colisiones de dos partículas en una superficie bidimensional. Tales experimentos emplean dos cilindros que se mueven sobre la mesa con una fricción mínima debido al cojín de aire producido por ellos mismos, lo que les permite moverse casi sin fricción sobre la superficie del vidrio. La investigación descrita condujo al diseño de un software de procesamiento de imágenes en el que se desarrolla un algoritmo para adquirir, procesar y registrar la trayectoria de dos cilindros que se mueven sobre la mesa con un mínimo de fricción. Para llevar a cabo esto se realiza un estudio de los experimentos hechos sobre la mesa y mostrados en el papel metalizado de registro. Basándose en los resultados, esta herramienta digital está diseñada para reemplazar el papel y permite a la comunidad académica utilizar esta tabla de manera sostenible y sin depender de insumos costosos. Adicionalmente, se analizó el error obtenido debido al paso de imágenes a través del algoritmo, resultando sólo un 3% del error total con respecto al obtenido usando el papel real.

Palabras clave: choque de partículas 2D, cojín de aire, procesamiento de imágenes, umbral.

1. Introduction

Table with air cushion Leybold Didactic Table (hereinafter called MLD) [1], [2] is a device that allows the qualitative and quantitative study in the movement of two dimensions. Two sliders with built-blowers, move almost without friction on an air cushion. The temporal behavior of the movement can be displayed on a metallized paper that records and reacts to electrical impulses generated by an electrode located on the lower center point of each slider. In the MLD permitting tests as uniform linear motion, rectilinear uniform acceleration, and top center of gravity among others. Unfortunately the MLD is not used by the high cost of metallized paper

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record whose value exceeds $ 650,430 Colombian currency excluding tax, in addition to the 18 or 20 weeks it takes to import from Germany.

1.1 Work Overview

The project is developed in the design of a prototype software for recording experiments, with which by means of a camera information is acquired to perform image processing (on a video previously recorded by the same software) to each frame that supplying said device, in order to identify two objects moving across the surface of the MLD and record their movement.

The aforementioned objects are two cylinders that produce a cushion of air, to glide over the glass table with little friction, the cylinders are used to simulate some types of crashes. To study this event, we need to know the path, speed and acceleration at certain time instants; this occurs at the same time a camera records the experiment. Each frame that provides the camera is purchased by a software image processing, which executes an algorithm on the image to identify the cylinders and acquire data that allow the study of the experiments to carry out on the table, this process is illustrated in Figure 1.
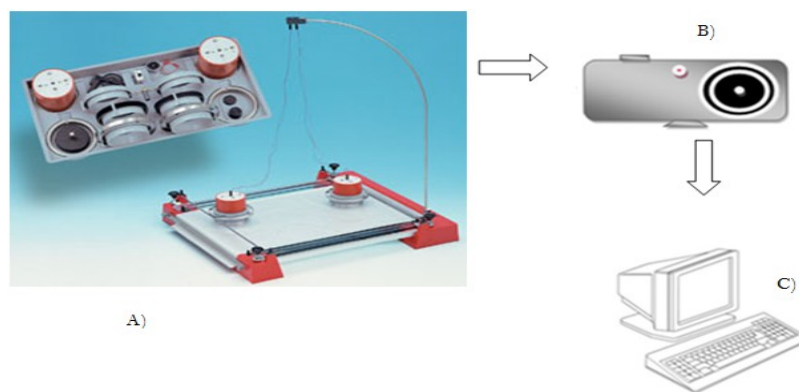

Figure 1. General description, a) MLD; b) Web camera; (C) Prototype software on PC. Source: [2]

2 Software Development

The development environment used for this work was Matlab® [3]; thanks to the versatility, range, performance and options toolkits; Imaging (Image Acquisition Toolbox), image processing (Image Processing Toolbox) [4], which allow management functions for acquisition, analysis and processing of images and matrixes as well as a tool for creating graphical interfaces to give a comfortable product to the end user. This prototype is named 2D GRAPH software.

2.1 Image Acquisition

Matlab has algorithms to identify the connected video devices, video formats supporting the device, and the resolutions could be delivered, the number of frames per second and more. Based on these features a webcam capture device is selected, it has a USB cable that is the channel of communication with the computer. The device must meet two conditions for optimal performance 2D GRAPH software that have an acquisition format 'RGB24_640x480' pixels and deliver at least 10 fps.

Webcam strategically located to focus the surface of the table on which the cylinders are moved to this mechanical structure and is secured to the base of the table and has a mast on which the position is set is implemented the camera. Later from a computer running 2D GRAPH software where a window with a background image and buttons on the right side and top opens as shown, in order to make a nice graphical environment. It is easily operated and for the user, some of the buttons are enabled or disabled depending on the function that executes at the time. Figure 2.
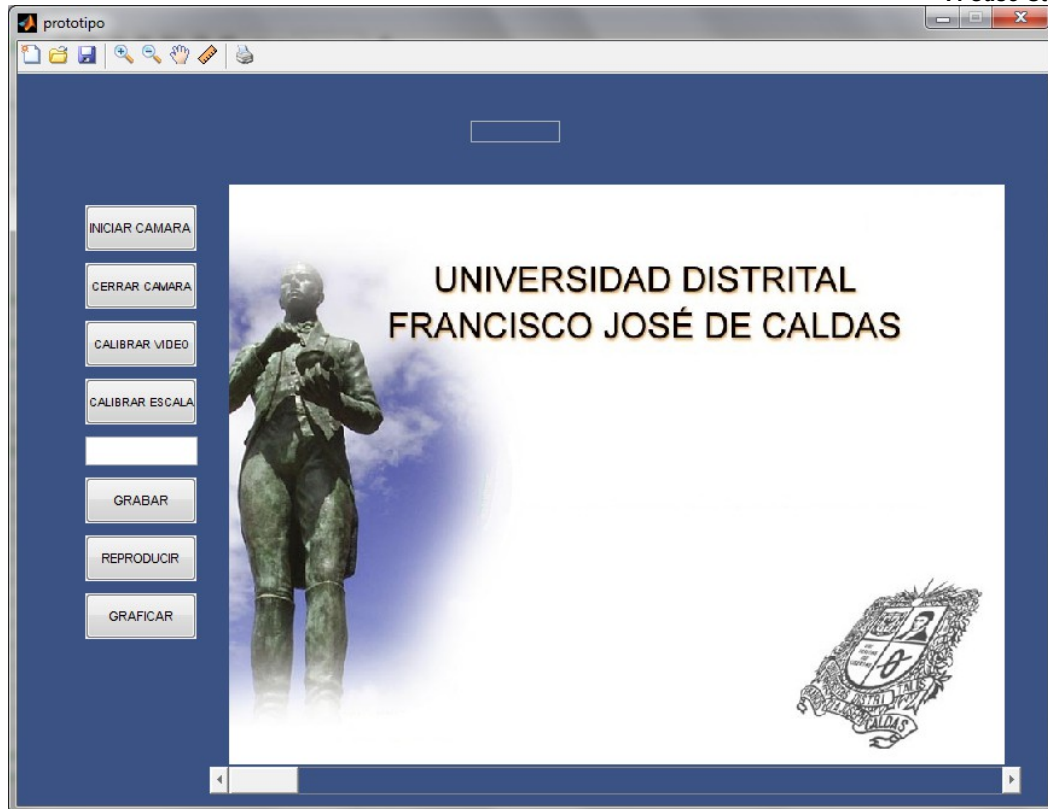
Figure 2. Graphic environment. Source: own

2.2 Focusing the Camera

At the start, two buttons will be enabled to open the chamber and plot, this first run is for the algorithm to initialize communication with the camera to acquire images supplied and display real-time experiment. This button is useful to check that the camera is in focus.

2.3 Calibration lighting and scale

A function is implemented to determine the amount of lighting in the room, to avoid errors in the algorithm abundance or absence of light produced by varying the intensity of the colors, [5] this is done by taking a picture of the surface of the table without cylinders in it, for the average red, green and blue (equation 1) in the image. Taking the three values is averaged again, but among

the three values previously found (equation 2) and finding the lighting factor [6] that determines

the threshold values for detection of the cylinders.

$$R = \frac{\sum_{i=0}^{m\,max} \sum_{j=0}^{n\,max} x_r(i\,,j)}{(m)(n)}$$

$$G = \frac{\sum_{i=0}^{m\,max} \sum_{j=0}^{n\,max} x_v(i\,,j)}{(m)(n)} \qquad (1)$$

$$B = \frac{\sum_{i=0}^{m\,max} \sum_{j=0}^{n\,max} x_a(i\,,j)}{(m)(n)}$$

$$L = \frac{R + G + B}{3} \qquad (2)$$

(i, j)	Row-Column position
(m,n)	Matrix dimension
R	Red average value
V	Green average value

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A	Blue average value
L	Light average value
X(i, j)	Numeric value of matrix in position (i, j).

Another function is a calibrated scale that allows finding a measurement ratio without relying on a predetermined focus distance [7]. To achieve this object which is located on the surface of MLD will give you have prior knowledge of its size (100mm), it takes a photo and a measurement tool ends are manually identified, this sets the ratio to calculate the distance approximate motion on the table surface [8]. This procedure is described in (equation 3).

$$
\begin{aligned}
pe &\rightarrow 100 \\
np &\rightarrow dc
\end{aligned}
\qquad
dc = \frac{np*100}{pe}
\qquad (3)
$$

pe (3) pe	Equivalent pixels 100mm
np	Measured pixels in the graph

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dc	Computed distance

2.4 Recording video:

Moreover, as the lighting and the distance scale we have on the table only remains to name the video you want to create. The analysis of data obtained by the camera is performed on a pre-recorded video, which process is run from the same software with the SAVE option, which is enabled when the camera is active, with real-time video, lighting and scale defined and focused to view all MLD. The video length should not exceed one minute, completed the experiment stop button is pressed will be the only one available to drive. The image processing is performed on a video to monitor and ensure that this action on all the frames that compose it done [9], [10].

2.5 Graphic path

The sequence of images obtained by the camera to determine the method of identifying objects on the images to use is analyzed [11–13]. It states that Thresholding is the best way to identify the cylinders. It is obtained from a constant calibrated Thresholding lighting that applies to 255 shades of red, green and blue components of a color image (its acronym in English is established RGB) [14], [15]. To identify each cylinder separately, a cover of blue and green suits, this in order to plot each path independently. In function graphing much of the image processing is implemented to use in the project. Once known Thresholding values obtained based on calibration lighting are analyzed one by one frame of the video, the thresholds are calculated and applied morphological operations such as erosion, dilation and closing on each image. This applies to ensure circular cylinder surface is a shape.

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Thresholding:

Thresholding can be seen as an operation that involves making checks against a T function of the form shown in equation 4.

$$T = T\,[x, y, p(x, y), f(x, y)] \tag{4}$$

Where *f(x, y)* is the gray level of the point *(x, y)*, *p(x, y)* represents a local property of this point, for example, the average gray level in a neighborhood centered on *(x, y)* [5]. A threshold image *g(x, y)* is defined as it is shown in equation 5.

$$g(x, y) = \begin{cases} 1 \; si \; f(x, y) > T \\ 0 \; si \; f(x, y) \le T \end{cases} \tag{5}$$

Thus the pixels marked with 1 (or any other suitable intensity level) corresponding to objects, whereas the pixels labeled 0 for the background [1].

Erosion:

For sets A and B of Z2, erosion of A by B. $\ominus$B represented by A it is defined as it is shown in

equation 6.

$$A \ominus B = \{x \,|(B)_x \subseteq A\} \tag{6}$$

It says that the erosion of A by B is the set of all points X such that B, translated by X, is contained in A [1].

Dilatation:

With A and B as Z2 and $\oslash$ sets representing the empty set, dilation of A by B, represented by A

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⊕B is defined as it is shown in equation 7.

$$A \oplus B = \left\{ x \middle| \left(\hat{B} \right)_x \cap A \neq \emptyset \right\} \tag{7}$$

Therefore the expansion process is to obtain the reflection of B about its origin and then change this reflection by x [7]. Dilation of A by B is then the set of all offsets x such that B and A overlap in at least one nonzero element [1].

Closing:

A closure assembly for the structure element B, represented by A·B, is defined as it is shown in equation 8.

$$A \cdot B (A \oplus B) \ominus B \tag{8}$$

That tells us that the closure of A by B is simply the dilation of A by B, followed by erosion result B [1].

Later another function that provides the central point coordinates x, y of the circle is executed, the central points of the cylinders are stored in a matrix below is indexed to obtain the coordinates of each cylinder and graph them, some points on the graph together to obtain the path in phantom. These processes are related in the manner shown in Figure (3).

Based on Figure 3 each set of instructions for the function specified:

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Image acquisition: This section features a video previously levied on which the image processing is performed.

Lighting calculation factor: It takes one of the images that are acquired earlier and converted to grayscale, then the image is averaged to find enlightenment factor. RGB filter threshold of each cylinder: Knowing luminance factor is related to the set for each color filter, an image of the cylinders is obtained with some elements that are able to overcome the noise filter.

Filtering the image for area: A technique is applied to remove elements with areas that are smaller than the average of the cylinders.

Morphological operations: a morphological dilation technique is used to coat the insides of the cylinders did not pass the filter, in addition to another technique, the closing time is given a circular shape to ensure complete interpretation of the cylinder.

Storing center points in a matrix: With fully identified cylinders center of each of them are calculated in coordinates X, Y that are stored in an array.

Graph array data: Access to the matrix of coordinates to plot a middle line between the points previously established reference, this tour of the cylinders is obtained.
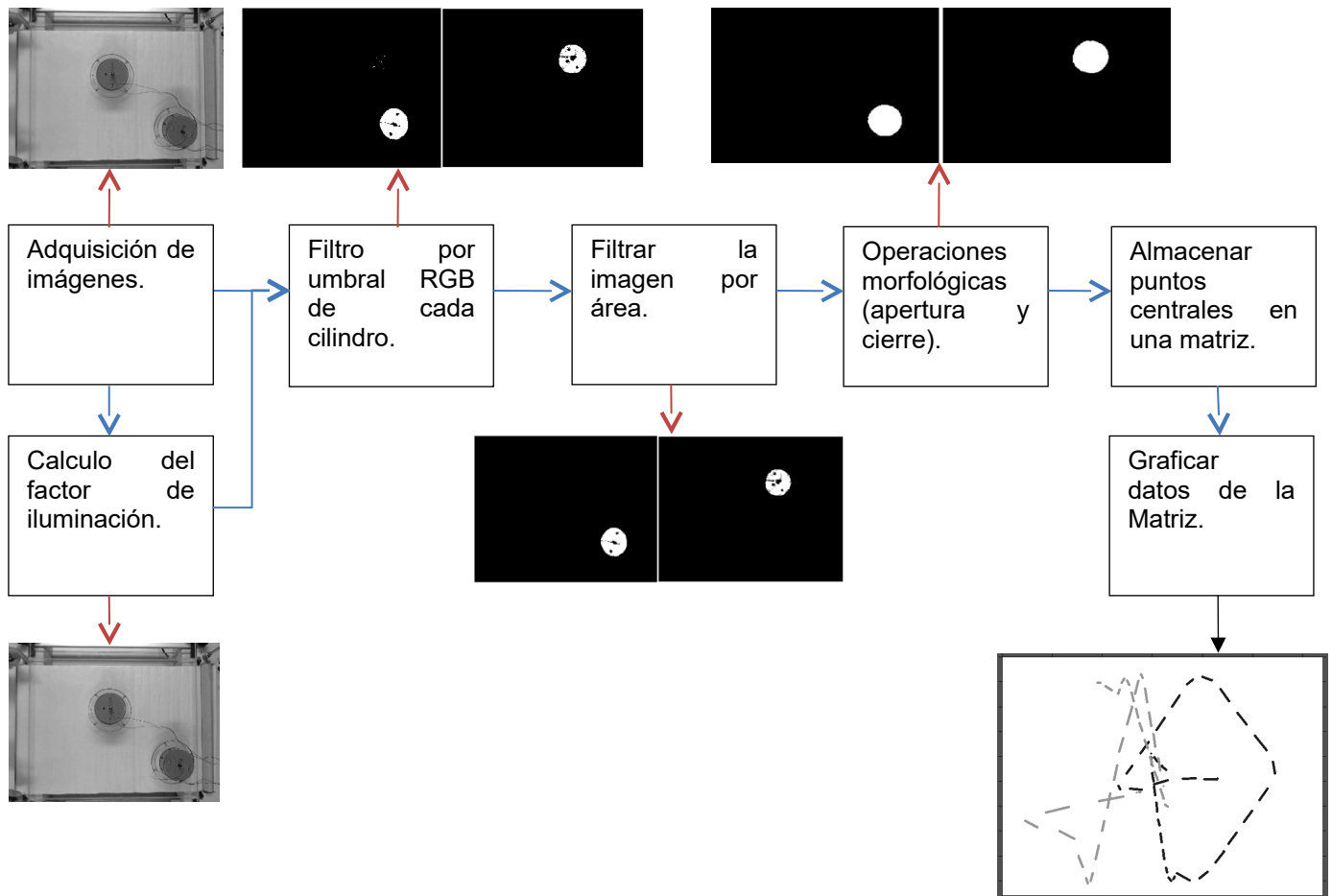
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Figure 3. Flow diagram of image processing to obtain cylinders position. Source: own.

The result of this process is shown in the graph window environment as shown in Figure 4.

2.6 Software Tools

Obtained graphical path cylinders the New File functions are enabled, open, saved, measured and zoomed. These tools are created for the user to easily manipulate the graph achieve delivered by the software. When using the saved chart and an array of points obtained they will be transferred to the folder where the software is running, resulting in an image of the path and a file that can be used to open the path from 2D GRAPH software. With the graph obtained,

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either by a previously saved or generated by a just performed experiment that can measure any of the lines that make the path of the cylinders, this is done by icon as rule located on the toolbar at the top. When this is done on the screen two small boxes connected by a red line, which can be placed with the mouse pointer at the ends of what is measured. Taking the checkered positioned the measuring tool is disabled, the distance is calculated in relation to the range obtained before recording the video and the software provides the approximate extent a text box at the bottom of the screen. Described above can be seen in Figure 5.
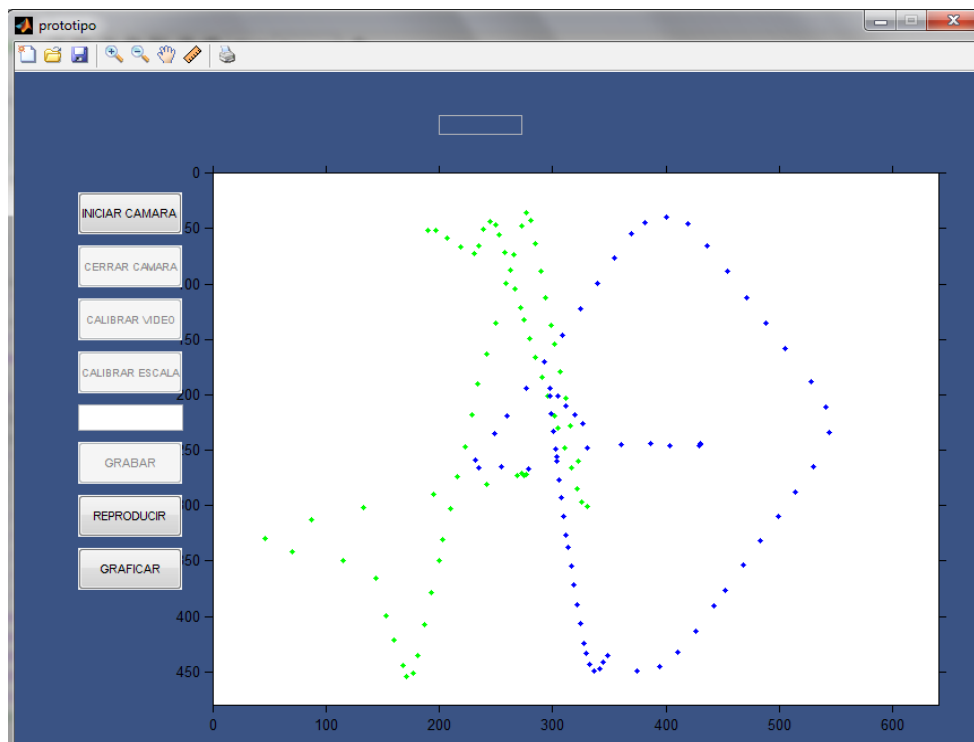

Figure 4. Plotted path.Source: Own.

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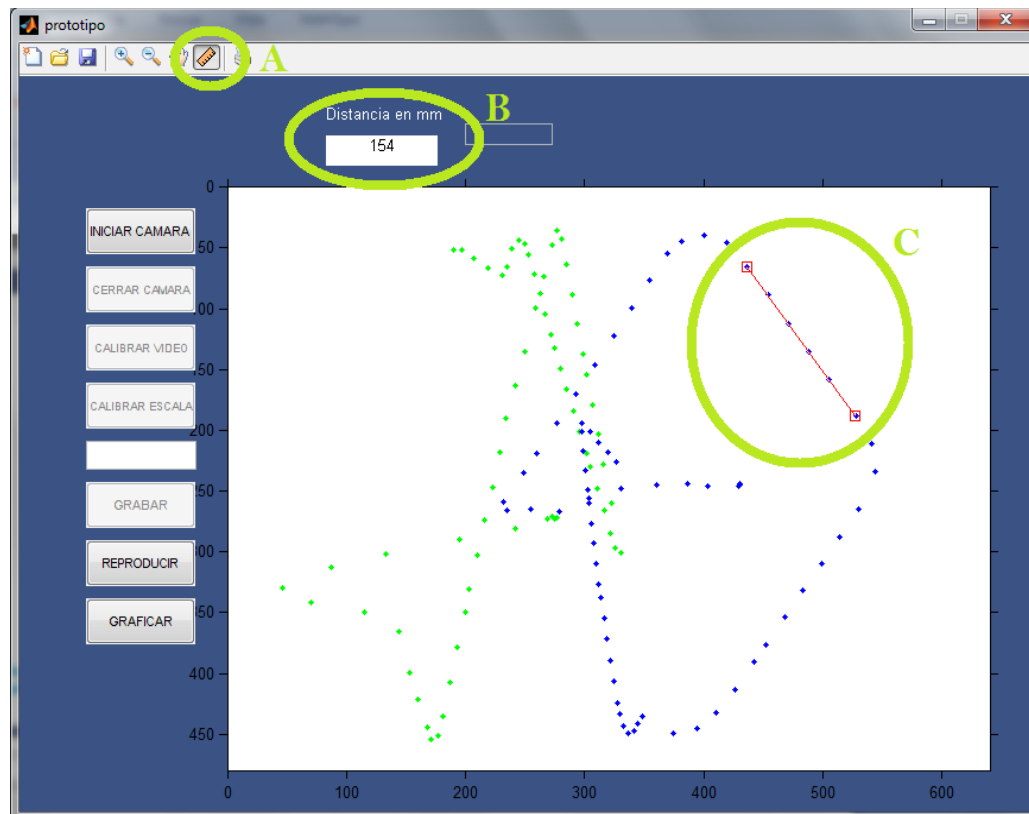*Fecha de aceptación: julio 2016*

Figure 5. Software Tools: A. Icon measuring tool, B. Text box showing the extent C. cursor to locate the points to be measured. Source: own.

Finally knowing the distances provided by the software allow users to make calculations of the experiments in the same way as was done with expensive metallized paper record.

3. Conclusions

Using 2D GRAPH software a significant saving is achieved in the operation of the MLD because the use of metallized paper registration is not necessary. In addition the use of MLD is achieved that currently is not used.

In image processing, it depends largely on the quality of the original image, care should be taken to ensure adequate lighting of the environment in cases where the processing is performed on images that are affected by it, to avoid failures in the analysis of the image.

In an effort to facilitate the work of placing the camera for data acquisition was decided to make a mechanical structure to hold the table and hold the camera.

The table with air cushion, by plotting the electrode has the option to change the sampling frequency is 10 Hz to 50 Hz and vice versa. In 2D GRAPH software it should not reach frequency of 50 Hz, because the current capture device offers maximum 30fps.

A device that delivers 50 fps is achieved, it might not work properly with Matlab in real time due to the time of execution of the algorithm. You could search other software processing images that have a shorter execution.

It is not required in applications of instant image processing or real-time response. It is an excellent choice to create a video to then perform processing, because processing usually requires many hardware resources that make slow response to a live video input.

With the software, it gets a better delivery of results to display colors struck by the fact that the recording paper paths are marked in the same color that paths can be mistaken together.

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