DEVELOPMENT OF A SOFTWARE FOR THE PLANTAR FOOT PRESSURE MEASUREMENT

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Abstract. The measurement of the plantar pressure has been used in evaluations, treatments and products development. There are two basic techniques, the in-shoe and off-shoe (inside and outside of the shoe), and the measurement can be made through mechanical or optical sensors. The objective of this work was the development of a software to be used with the off-shoe technique, with images captured from to scanner (sensor optical). The images were digitalized with resolution of 100 dpi and with the scale of colors set to "grayscale." Afterwards they were processed, altering their colors and calculating to plantar pressure values. The post-processed images revealed the areas with high plantar pressure, providing aid to physician, physiotherapists and other professionals to evaluate, diagnosis and treat diseases and deformities of the feet.
Keywords: Podoscan, scanner, foot, image analyses

1. Introduction

The plantar pressure is a measurement accomplished in the patients' sole and its study has been used by several researchers as method of evaluation of treatments, as parameters for the development of products and of special inner soles [Cavanagh et al., 1994, Chang et al., 2002, Santos et al., 2001, Arndt et al., 2003].

One of the study areas is the development of ulcers in feet of bearers of diabetes. The appearance of these ulcers can be linked to alterations in the foot's biomechanics, including limitations in joints mobility, abnormality of the bones and to increase the plantar foot pressure [Merza et al., 2003; Cavanagh et al., 1994]. These ulcers can take to the amputation of the diabetic foot due to the ischemia or infection [Levine et al., 1995].

The analysis of plantar foot pressure is also important for diagnoses, evaluations of treatments and surgeries of deformities in the foot, as the deformities in valgus and in varus [Chang et al., 2002].

There are two basic techniques for measurement of plantar foot pressure, the in-shoe and off-shoe. The technique in-shoe uses an inner sole with several sensors of force or pressure inside of shoe. An advantage is a dynamic and real measurement of the pressure, and the disadvantages are the use of threads and cables of transmission of the sensors and a possible alteration of the real situation due to use of the measurement system inside of the shoe [Finch, 1999]. The in-shoe systems are EMED and F-Scan [Finch, 1999, Lord, 1997]. The off-shoe system is simple, could be used easily at clinics by doctors and physiotherapists. However, it possesses the disadvantage of accomplishing the pressure measure without the shoe, what becomes less suitable for the project and improvement of shoes. Other equipments use sensors of force or pressure for the acquisition of plantar pressure map. Some new equipments use optical system, like Foot Scanner developed by the University of Kentucky [Hassebrook et al., 2005], Solescan / PodoScan developed by Sculptaped Inc. [Sculptaped Inc., 2005] and PodoScan developed by the Íon Indústria in partnership with the Laboratory of Bioengenharia of UFMG [Íon Indústria, 2005].

2. Objective

Developing a software that it will be used in group with a modified scanner (PodoScan, developed by the Íon Indústria) to determine areas of plantar pressure concentration is the aim of this study.

3. Methodology

The image was captured and was realized a manipulation to emphasize the high plantar foot pressure areas. Besides this, calculus was made to obtain the values of the plantar foot pressure and the contact area.

3.1 Standards of the captured images

The tests images were scanned with resolution of 3,937 points by millimeter (100 dpi) and in 256 gray tones, after a first analysis, these images were adopted as pattern due to reasons:

• Small size of original image;
• Faster processing;
• Easier for the development of the software.

3.2 Type of used treatment

Some tests with filter in images captured with PodoScan were realized. The best that one which modified the original colors of the image, put them in a similar colors scale of the cameras thermograph and of the programs of finite elements, among others (Figure 1). The colors vary according to the blood flow: blue one in areas with a high blood flow (smaller pressure level) and red one in that with a low blood flow (larger pressure level).

Figure 1. Colors scale used. The blue represents the area with smaller value and the red with larger plantar pressure value.

3.3 Software - Division in modules

The first step for the software development is the creation of their diagrams and algorithms. In this case, it was organized a general diagram (Figure 2), presenting some modules and, to proceed, these modules went forming other diagrams or separate algorithms. Among the modules only "Process" will be described in this article, once the others treat of common programming techniques, without aggregating of new knowledge.

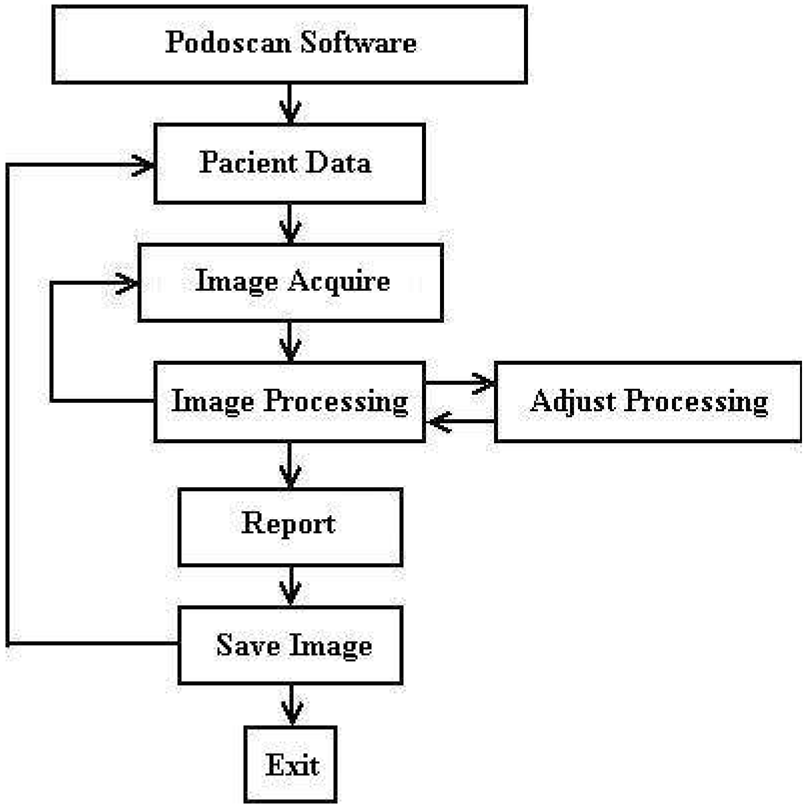

Figure 2. General designs showing the division of application in modules.

3.3.1 Software-Module "Process"

This module has the structures of image processing (Figure 3) and the calculation structure of plantar foot pressure in function of shade color image (Figure 4). This module needs that the image has already been carried in the program and more three parameters:

• FiltroA: it is the filter "passes low" of the image; it is represented by a number from 0 to 255 that is related with the largest color (according to the scale of Figure 1) visible in pre-processed image.

• FiltroB: it is the filter "passes loud" of the image; it is also represented by a number between 0 and 255, but it should be smaller than FiltroA. It is related to the smallest color of the foot contact area with the surface of PodoScan.

• Peso: it is the patient mass; used for the plantar foot pressure calculation.

These two filters select the area that will be used for the plantar foot pressure calculation. For this calculation it was defined as initial condition that the color variation in relation to plantar pressure is linear, in other words, the variation of a tone results in a pressure area with value base (variable *m* of the Figure 4) multiplied by an added factor of a unit. This pressure value is corrected due to the difference of size scale understood between FiltroA and FiltroB (smaller than 256 colors) and the gray scale (256 colors).

The result of the calculation will be a vector of 256 positions, each position containing a plantar pressure value corresponding the color acted by the number of the position in the same vector.

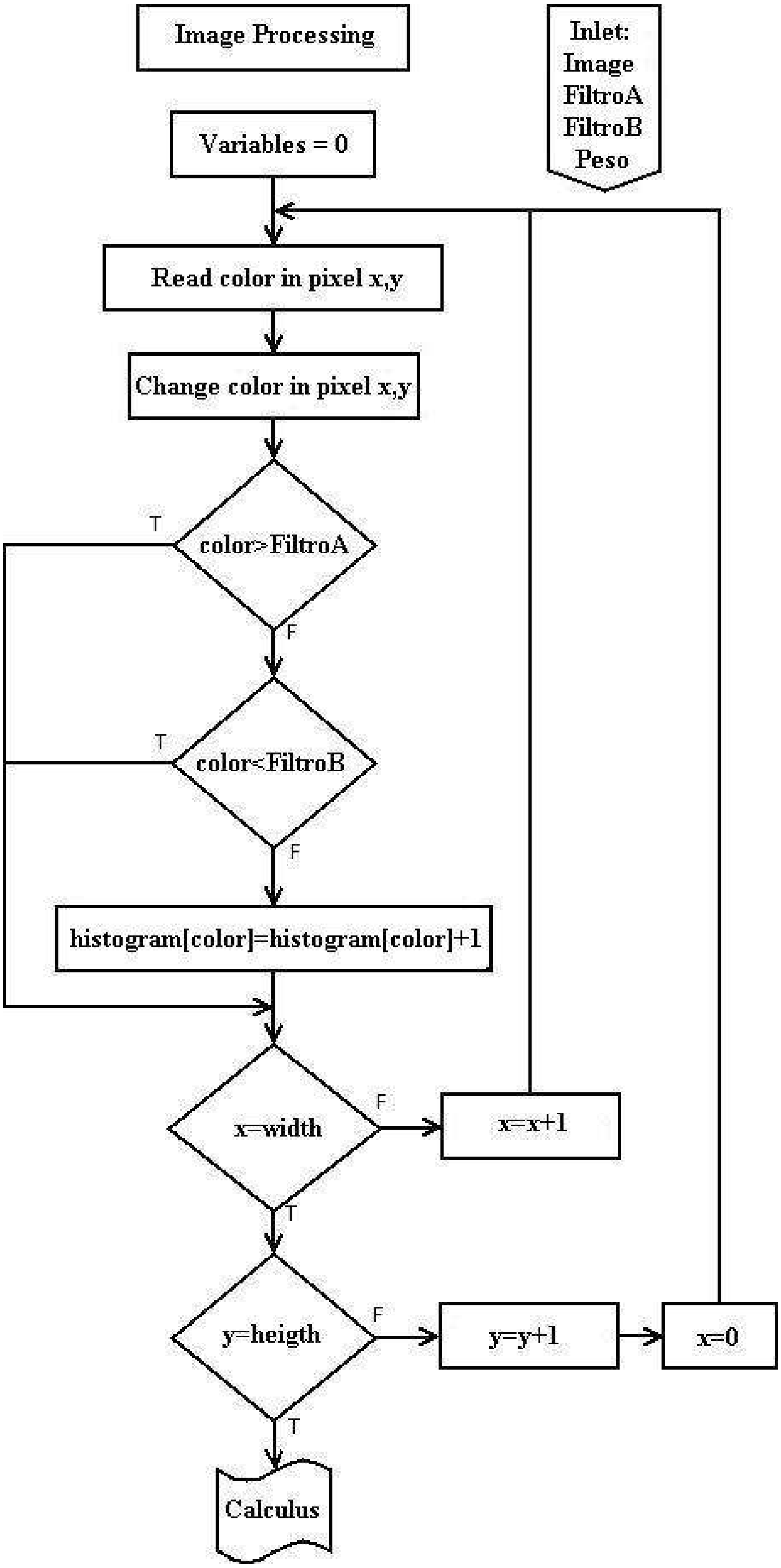

Figure 3. Algorithm “process”. This module will read all image pixels, will create a vector “histogram” and will pass this to a calculus routine.

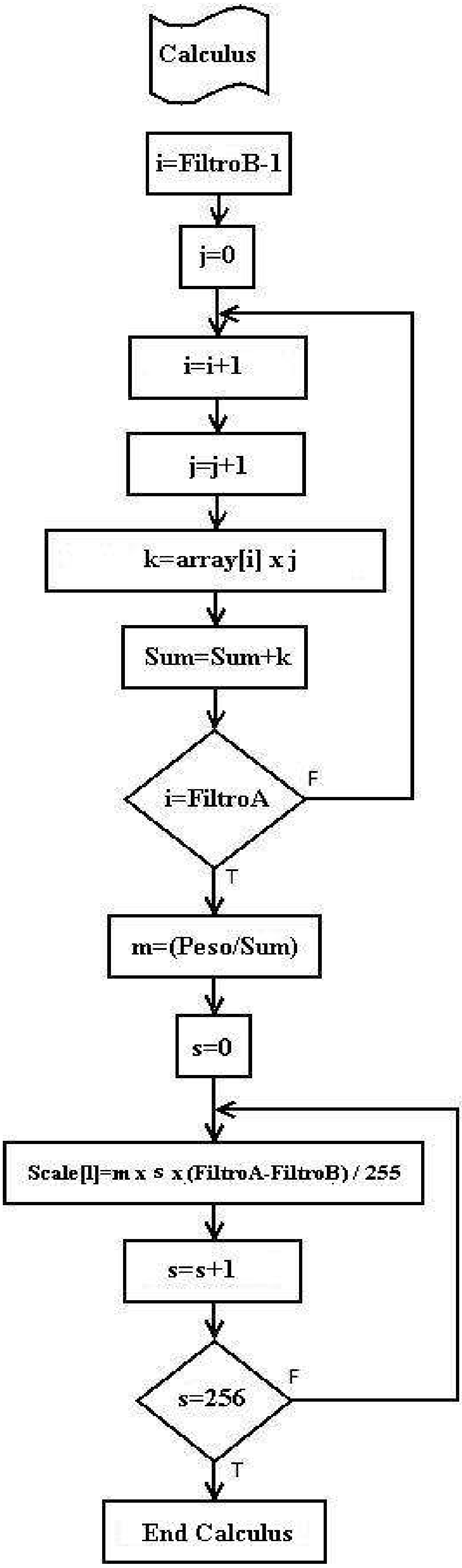

Figure 4. Algorithm “Process”, sub-algorithm with the calculus routine. In this routine will be calculated the plantar pressure value, using a linear ratio between the color and the pressure. The variable i and j are auxiliary, m is the base value of plantar pressure, it represents the smaller value of pressure (the blue color). Scale is a array, it stores all plantar pressure value for the color scale.

4. Results

Many images were obtained to test the equipment, some are introduced in the Figure 5, being omitted all the patients data once the objective of this work is a software development and no a doctor case study.

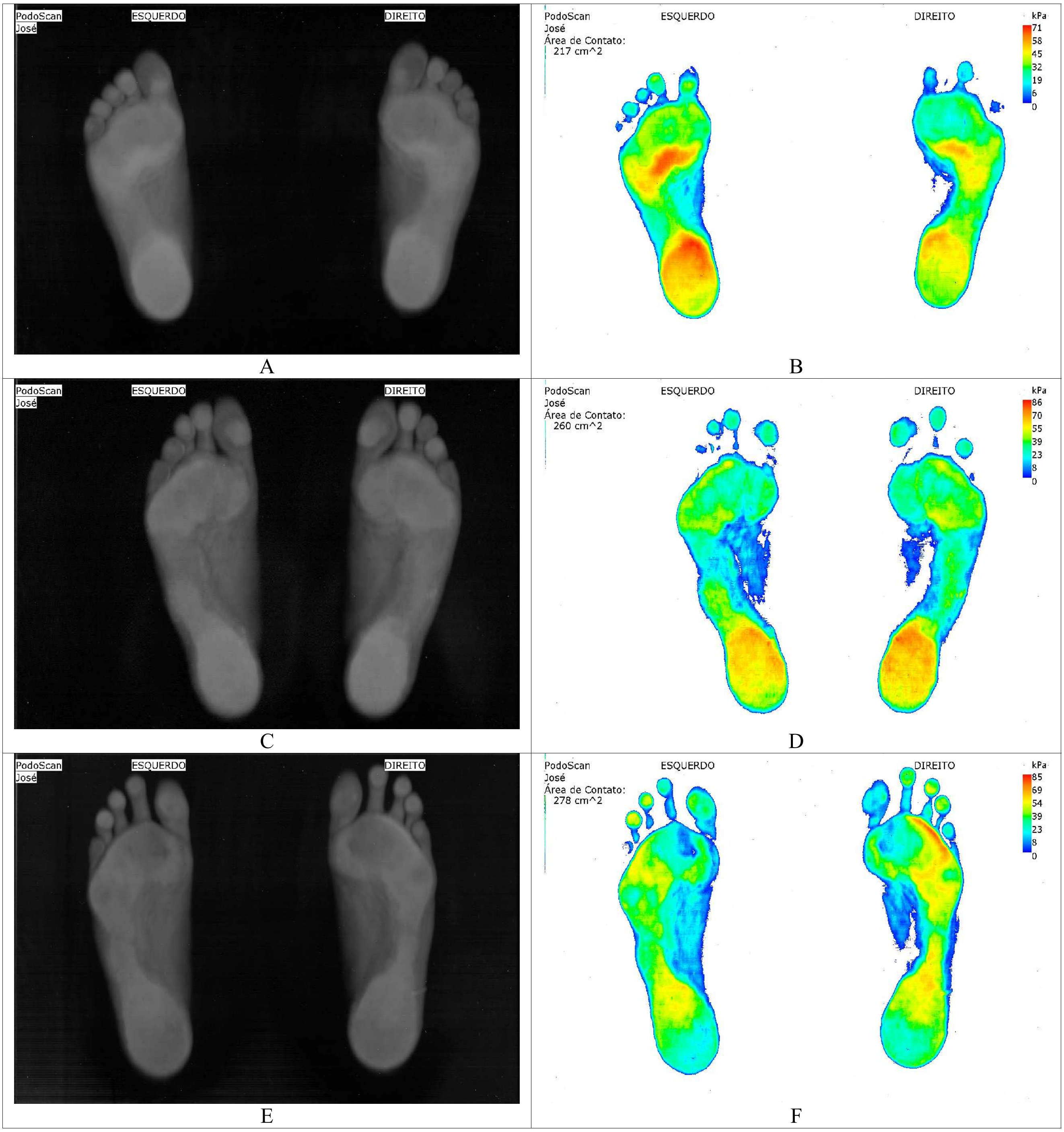

Figure 5. Images analyzed by the software. In A and B the first patient, the analyzed image presents a pressure concentration larger in patient's left foot. In C and D a pressure concentration in the area of the heel. In E and F other patient with pressure concentration in small area of the right foot.

The table 1 presents a values' summary found for these exams where a similar behavior can be observed.

Table 1. Results of the three presented exams

Exam	Maximum pressure (kPa)	Contact area (cm2)
Exam 1 (Fig 5A and 5B)	71	217
Exam 2 (Fig 5C and 5D)	86	260
Exam 3 (Fig 5E and 5F)	85	278

There is a small difference among the results and the high plantar pressure areas could be emphasized, using a pixels smaller than the sensors based equipment, resulting in clean and homogeneous images.

The processed images were useful to aid in diagnoses, emphasize the points with larger pressure. However some mistakes of the equipment and developed software can be mentioned:

- A lack of information about the location of the patient's gravity center, factor that can determine in which areas of the feet the patient is leaning;
- The linear relationship between the image colors and the value of the plantar foot pressure was defined as being an initial condition of the problem; it should still be analyzed and adjusted with the aid of another system of measurement of this pressure.

5. Conclusion

The system produces a homogeneous and clean image, with small pixels, and emphasizes the high plantar foot pressure areas. The generated images can be useful to aid doctors, physiotherapists and specialists in treatment and diagnoses.

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