

DEVELOPMENT OF A SOFTWARE FOR EVALUATION AND CONTROL OF SENSITOMETRIC CHARACTERISTICS IN AUTOMATIC FILMS PROCESSING*

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Abstract **OBJECTIVE:** To develop of a software tool for evaluation and control of sensitometric curves. **MATERIALS AND METHODS:** A method was developed for obtaining high- and low-contrast films sensitometric values, with no need to define wedge steps. **RESULTS:** The software named Sensito was implemented and tested utilizing data of sensitometric strips from conventional radiology, hemodynamics, and mammography departments. The feasibility of analyzing sensitometric curves from these areas remained evidenced with no need of user-dependent adjustments, and with no deviation in the evaluated sensitometric parameters and variations. **CONCLUSION:** The software allows the creation of a database including sensitometric curves from different processors in a same institution, easily generating gamma curves of a register and constant charts of the evaluated sensitometric characteristics, constituting an important tool for sensitometric control. *Keywords:* Automatic processor; Sensitometric curve; Sensitometry.

Resumo *Desenvolvimento de um programa computacional para avaliar e controlar as características sensitométricas em processamento automático.*

OBJETIVO: Desenvolver um programa computacional para avaliar e controlar as características das curvas sensitométricas. **MATERIAIS E MÉTODOS:** Para o desenvolvimento do programa, foi elaborado um método de obtenção dos valores das características sensitométricas, de filmes de baixo e alto contraste, sem a necessidade da fixação de degraus de referência. **RESULTADOS:** O programa, denominado Sensito, foi implementado e testado utilizando dados sensitométricos de curvas características dos departamentos de radiologia convencional, hemodinâmica e mamografia. Ficou comprovada a possibilidade da análise das curvas sensitométricas destas áreas sem a necessidade de ajustes, dependentes dos usuários, e sem incorrer em desvios nos parâmetros sensitométricos avaliados e na variação destes. **CONCLUSÃO:** O programa possibilita a criação de um banco de dados de curvas sensitométricas para diferentes processadoras de uma instituição, gerando com facilidade as curvas sensitométrica e gama, de um registro, e os gráficos de constância das características sensitométricas avaliadas, fornecendo importante ferramenta para manter o controle sensitométrico.

Unitermos: Processadora automática; Curva sensitométrica; Sensitometria.

INTRODUCTION

Small changes in the automatic films processing may result in a significant loss or degradation in the quality of information recorded on radiographic images. Inadequate processing affects the image qual-

ity, demanding higher radiation dose for obtaining a satisfactory radiological image⁽¹⁾. Therefore, quality control is essential for guaranteeing the accuracy of x-ray-based diagnoses. For this purpose, sensitometry is one of the most effective methods for monitoring changes in conditions of the automatic images processing⁽²⁻⁴⁾.

The Order (Portaria) No. 453/98 of Secretaria de Vigilância Sanitária do Ministério da Saúde (Brazilian Ministry of Health National Sanitary Vigilance Agency)⁽⁵⁾ establishes that in a quality assurance program, a sensitometric test must be performed in the images processing system, at least weekly for conventional radiology, and daily for mammography. Considering that sensitometry is a way to indicate corrective measures to avoid deterioration of radiological images, it would be advisable

to perform this test on a daily basis, preferably early in the work routine, in order to avoid that images are affected by malfunctioning of the images processing system.

The evaluation of processing conditions by means of sensitometric curves analysis may be manually performed, although this method is time-demanding and may lead to miscalculations and discrepancies when different people analyze a same curve. Generally, the analysis is performed with the help of softwares provided by the radiological films suppliers themselves. This constitutes a limiting factor, since different softwares analyze sensitometric curves in a different way, that is to say, depending on the software utilized for a same sensitometric curve one may obtain a different value for characteristics such as contrast and film speed.

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The present study presents Sensito, a software tool for evaluation and management of sensitometric curves characteristics. A generalized way of analysis was adopted in the development of this software, therefore sensitometric curves can be evaluated by the same software in different modalities of Radiology, with no need of user-dependent adjustments, and with no systematic deviation in the evaluated sensitometric parameters and variations. If previously registered, non-conformities are automatically detected as the sensitometric curve graph is generated. The software allows the creation and maintenance of a database including sensitometric curves from different processors in a same institution, easily generating gamma curves of a register and constant charts of the evaluated sensitometric characteristics, which play an essential role in the images quality control⁽⁶⁾.

MATERIALS AND METHODS

The development of the software for sensitometric analysis demands the knowledge on the definitions of some specific characteristics of the sensitometric curve, or H&D curve⁽⁴⁾ (Hurter & Driffield), associating the film blackening degree, or optical density (OD) with the film exposure. Based on the sensitometric curve, it is possible to evaluate the contrast, latitude, gradient, film speed, and base+fog values. The foot of the curve corresponds to low density regions, and the shoulder of the curve corresponds to high density regions. The linear region of the curve corresponds to densities useful for diagnosis⁽⁴⁾, and hereafter will be denominated "useful zone", as shown on Figure 1.

The determination of the sensitometric curve characteristics undergoes a critical stage: the definition of the useful area of the film, since there is no step or specific density defining the beginning or end of this area, as it happens in some software tools or data collection protocols. This zone should only be characterized by the region where the sensitometric curve presents a linear behavior⁽⁴⁾. The center of this region is approximately the point of involution in the curve. Therefore, if a software is able to automatically generate an equation for

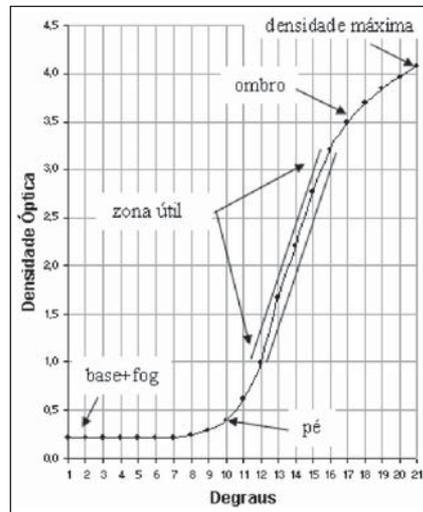


Figure 1. Sensitometric curve: base+fog, foot of the curve, zone useful for diagnosis, shoulder of the curve and maximum density.

to sensitometric data, the useful zone may be defined by means of a percentage variation in the correspondent maximum gradient of the involution point in the equation. Based on sensitometric data, adjustments were determined for representing the behavior of the optical densities data as function of the logarithm of relative exposure, represented by the hyperbolic tangent (*tanh*) function. Parameters were added to this function, generating the following equation whose values, on average, are compatible with the optical densities data of the sensitometric curves:

$$DO(x) = M \cdot [\tanh((x - PM) \cdot PASSO) + ZF] + BF$$

where: x represents the logarithm of relative exposure; PM is the logarithm of relative exposure concerning the sensitometric curve mean point; BF is base+fog, by definition, the optical density of the first step of the curve; $PASSO$ represents the equation growth swiftness; ZF corresponds to zero to start off with (zero factor principle); M represents the equation height. All the parameters are automatically determined according to the sensitometric data obtained.

The Figure 2 demonstrates the approximation of actual sensitometric data of a sensitometric curve with those generated by the adjustment curve. The data demonstrated that a 30% variation in the gradient corresponding to the involution point al-

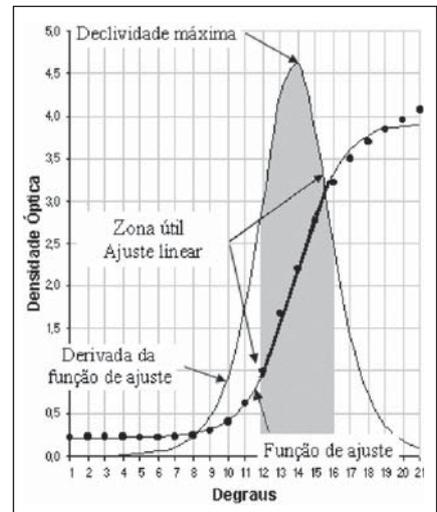


Figure 2. Graph demonstrating the useful zone and the linear adjustment of optical density values; note the 30% variation in maximum gradient.

lows the definition of a region where a straight line can be drawn, with a 99% linear relationship between this line and sensitometric data. The ratio was obtained through the square of the Pearson product-moment correlation. The straight-line equation is obtained by means of a linear adjustment of the optical densities in this region, as follows:

$$DO(x) = G \cdot x + A$$

where: x represents the logarithm of relative exposure; G is the curve gradient; A is a constant concerning the straight-line intersection point with the horizontal axis.

Based the straight-line equation G gradient, the useful zone, the sensitometric parameter of the gradient is estimated. The film latitude is obtained by the variation of the logarithm of relative exposure concerning the beginning and end of the useful zone, determined by the 30% variation in the maximum gradient. The contrast is a result of the variation of optical densities corresponding to the logarithms of relative exposure, of the steps utilized for determining the latitude which are estimated by means of the straight-line equation. The speed, corresponding to the reverse logarithm of relative exposure concerning the optical density 1 above the base+fog value, may be estimated by utilizing the linear adjustment as per the equation:

$$Speed = \left[\frac{1 + (base+fog) - A}{G} \right]^{-1}$$

RESULTS

The adjustment equation was tested for conventional x-ray, hemodynamics and mammography curves, as shown on Figures 3, 4 and 5. The values generated by the equation demonstrated a great similarity to the values of optical densities of conventional x-ray and hemodynamic films evaluated, with maximum deviation among density values lower than 7%. For the mammography film curve, as shown on Figure 5, there was a difference in values corresponding to the curve foot and shoulder, but, as it can be observed, the corresponding steps are similar in both curves, demonstrating a similar behavior between curve and equation. This reflects the points asymmetry on the curve describing the film behavior. However, the adjustment equation if utilized just for estimating the involution point of the curve, i.e., of the mean point in the useful zone of the curve and of the limits corresponding to the beginning and end of this zone. Therefore, the adjustment equation should present a similar behavior, mainly in the center of the curve to allow a more accurate estimation of the useful zone of the film by means of the gradient variation. This similarity in the behavior in the center of the curve was observed in all of the films evaluated.

Based on the described adjustment equation, a software tool for analysis of sensitometric curves was developed in C++ language, utilizing the Borland C++ Builder 6 compiler, and the Microsoft Ex-

cel application. This software denominated Sensito, besides analyzing the sensitometric curves characteristics, allows the generation of a databank to facilitate the sensitometric management of such characteristics, easily generating constant graphs.

The beta version of this software was tested by the Radiology Unit at Hospital de Clínicas de Porto Alegre, and modifications and adjustments were made to generate the first version of the software (Figure 6). Upon visualization of a curve in the processor data bank, the software indicates the occurrence of chemical replacement, processor cleaning, existence of any note linked to the register, or if the curve follows a standard (Figure 7). This information facilitates the sensitometric control; anomalies detected by the sensitometric curve in the films developing may be better understood with this type of analysis.

The sensitometric curves graphs, together with the standard curve, if available, are visualized on an Excel worksheet generated by the software itself. The space below the graph shows the base+fog value, film speed, contrast and gradient for both the present and standard curves. The present and standard curves deviations are shown on the column "Deviations", beside the column "Thresholds" (acceptance limit). If any of the values present a deviation higher than the acceptance limit, the note "Out-of-Limit" is shown, as it can be seen on Figure 8.

Concomitantly with the Excel graphs of sensitometric curves, a gamma curve concerning the visualized register is generated. The gamma curve may be a way of determining the ideal processing conditions, and, on the other hand, it may be useful for detecting processing problems⁽⁷⁾. Together

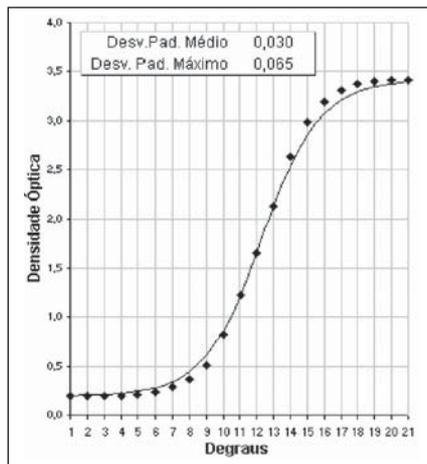


Figure 3. Graph demonstrating the adjustment curve values (continuous line) in comparison with the optical density of a conventional x-ray film.

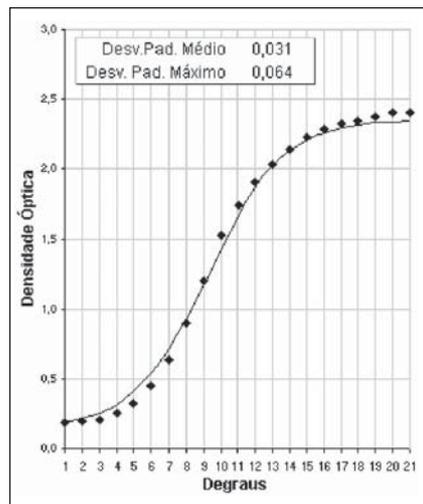


Figure 4. Graph demonstrating the adjustment curve values (continuous line) in comparison with the optical density of a hemodynamic film.

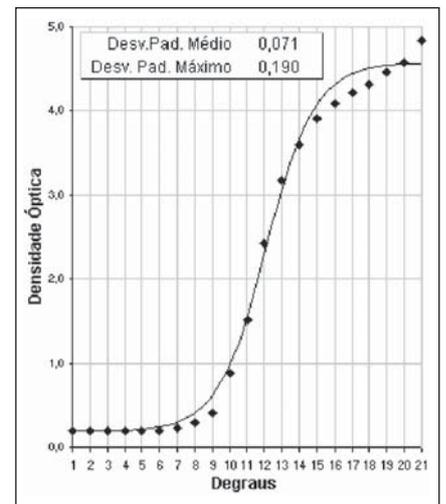


Figure 5. Graph demonstrating the adjustment curve values (continuous line) in comparison with the optical density of a mammographic film.

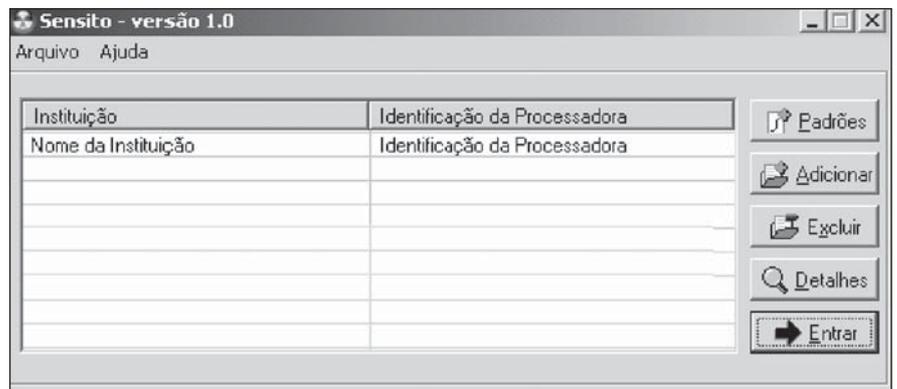


Figure 6. Sensito initial window.

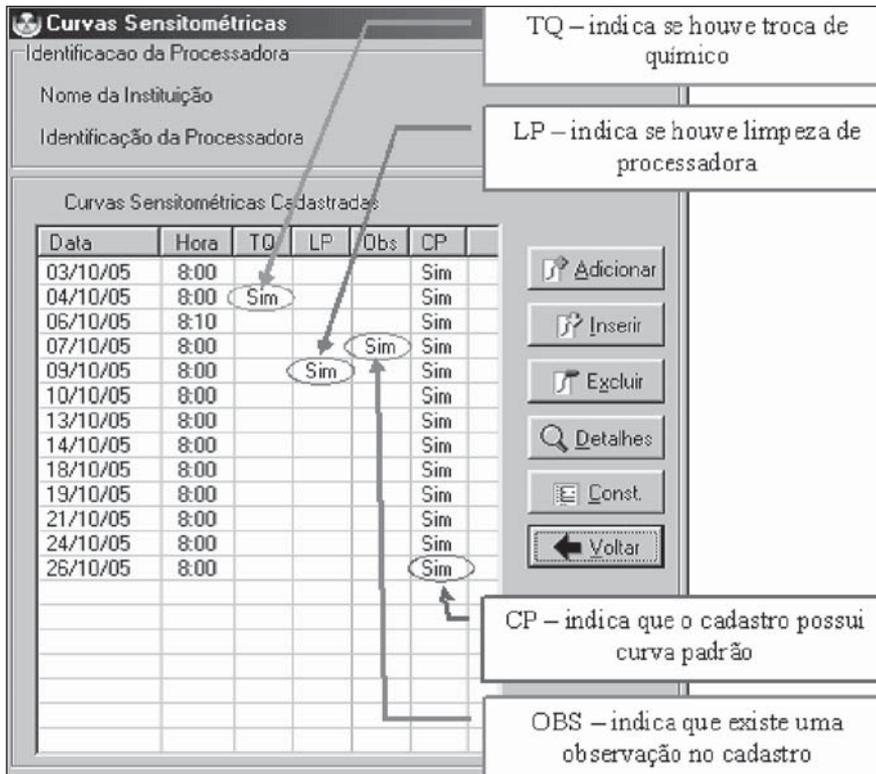


Figure 7. Databank registers showing the schedule of chemical replacement (TQ), processor cleaning (LP) and notes (OBS).

	Curva Atual	Curva Padrão	Desvios	Limites	Obs.
Base+fog	0,22	0,19	0,03	0,02	Fora do limite
Velocidade	0,86	0,83	4,12%	±10%	
Contraste	1,92	1,92	-0,17%	±10%	
Gradiente	3,13	3,14	-0,42%	±10%	
D _{máx}	3,45				

Figure 8. Detail of worksheet including the sensitometric curve, and a comparison with the standard values. The note "out-of-limit" was automatically generated, since the base+fog value presents a deviation in relation to the standard threshold, above the acceptance limit.

with the graph, the highest contrast found and the value of the area below the curve are displayed.

The constant graphs may be automatically generated from a mean value of a period defined by the user or from a standard curve. A constant graph demonstrates an interest-value (the speed rate, for example) as a function of time⁽⁶⁾. The base+fog, film speed, contrast and gradient data are orderly displayed on an Excel worksheet, together with the respective constant

graphs and acceptance limits, based on the mean interval values or the processor standard curve. The acceptance limits may be defined by the users.

The Sensito software is available for free download at: <http://www.pucrs.br/fisica/fimebi/gesic/sensito.htm>

DISCUSSION

Problems associated with radiological films processing still exist⁽⁸⁾ and should be

highlighted. The Sensito software was developed as an important tool for sensitometric control, with a quite friendly interface, and a manual including a step-by-step tutorial. More than 100 curves of films and different processors were tested aiming at validating the method for generation of sensitometric curves. The mean deviation between values of sensitometric curves and those resulting from the equation was lower than 10%. This result demonstrates that the adjustment equation is appropriate for the data to be analyzed. So this software can be utilized both for analysis of low-contrast films (in hemodynamics, for example) and high-contrast films (in mammography, for example).

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