

PGF5312 – 1 FUNDAMENTOS DE PROCESSAMENTO DIGITAL DE IMAGENS MÉDICAS

Aula 8 – Qualidade de imagens Parte 2

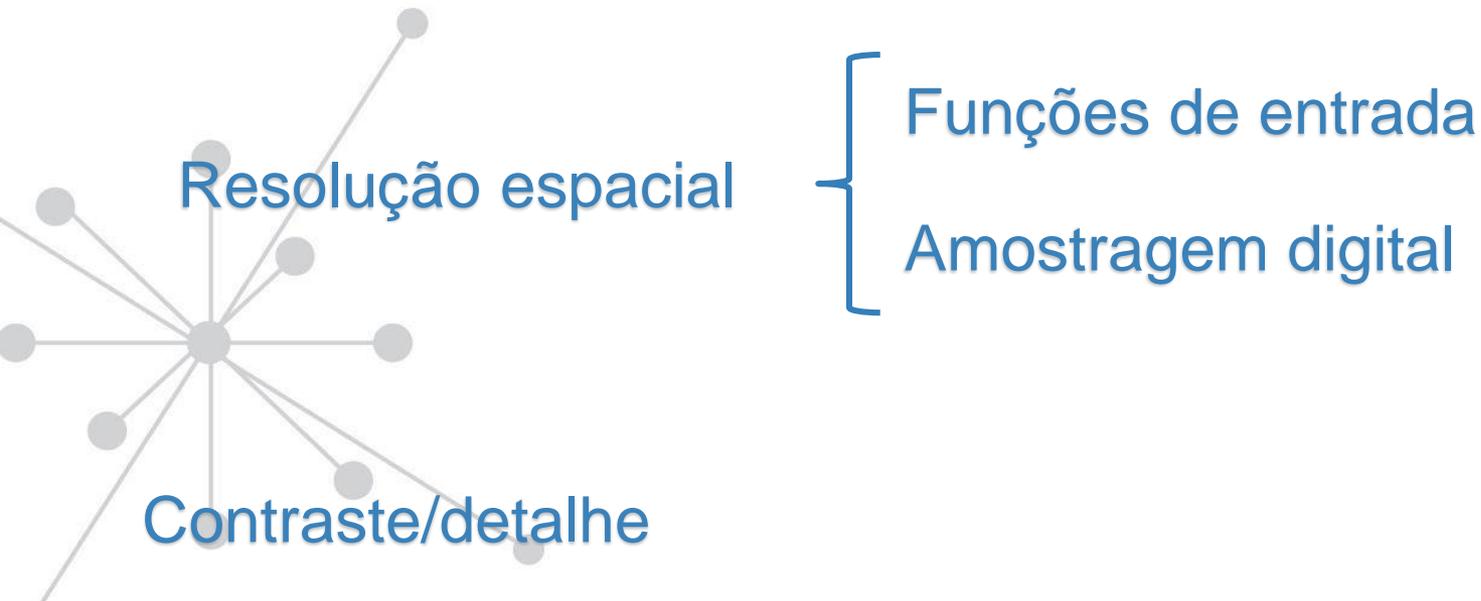
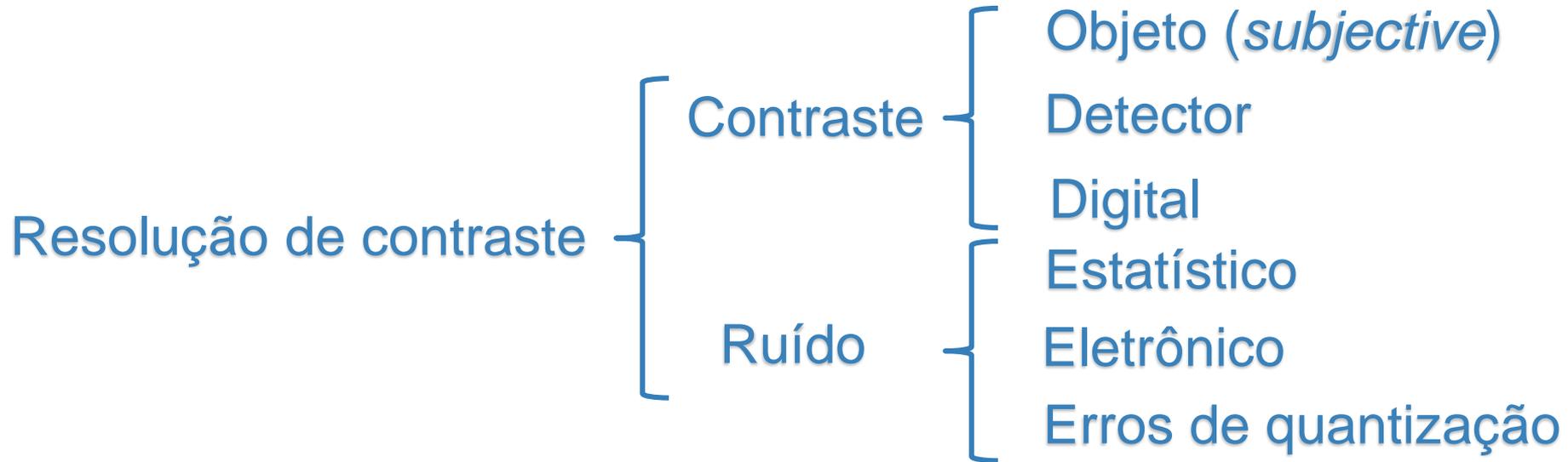
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Instituto de Física - USP



O que veremos hoje e nas próximas aulas



Qualidade das imagens

Resolução de contraste

Contraste

Objeto (*subjective*)

Detector

Digital

Estatístico

Ruído

Eletrônico

Erros de quantização

Resolução espacial

Funções de entrada

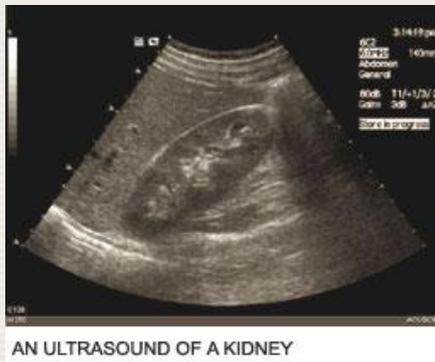
Amostragem digital

Contraste/detalhe

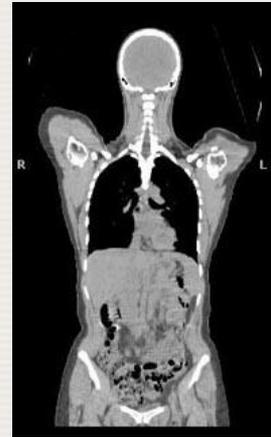


4.1 INTRODUCTION

A medical image is a Pictorial Representation of a measurement of an object or function of the body



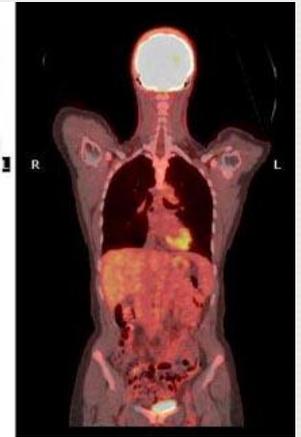
CT



PET

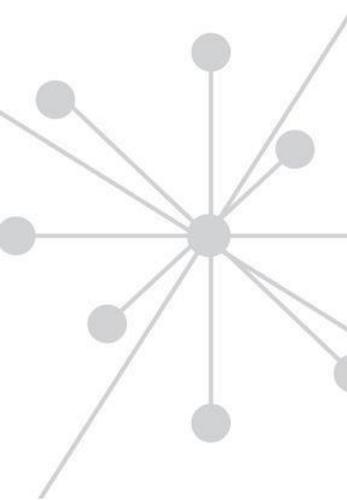
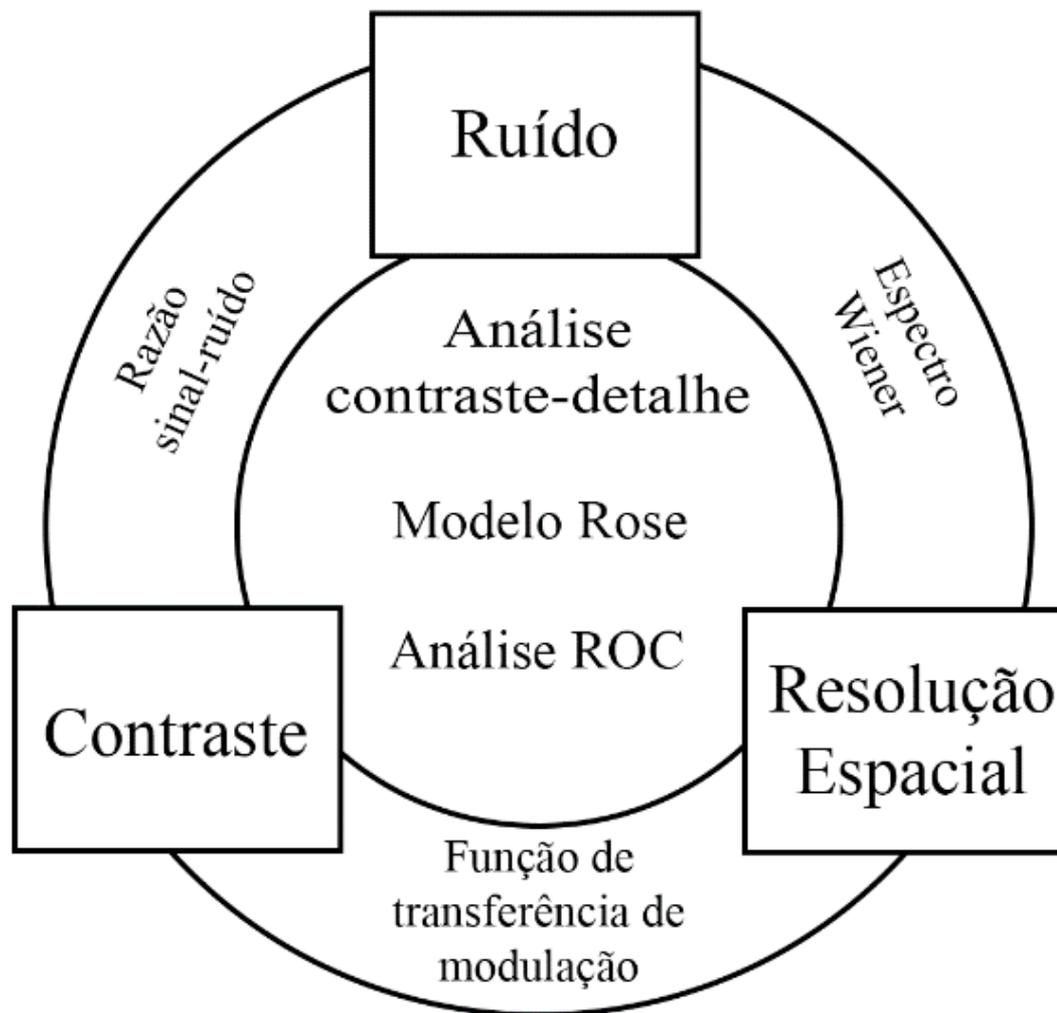


CT & PET Images superimposed



Many different ways exist to acquire medical image data

Qualidade de imagens



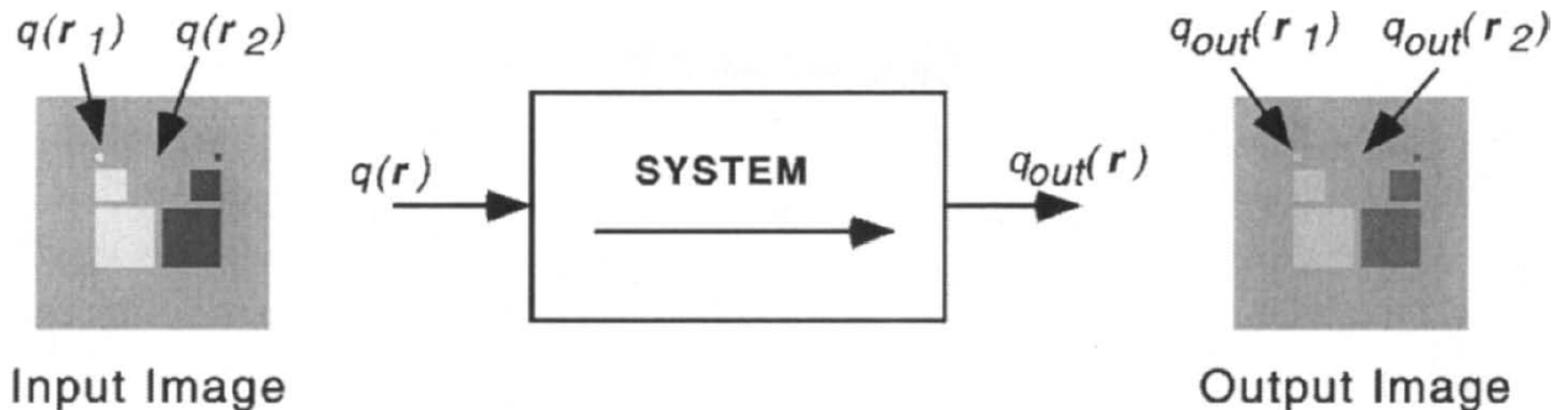


Figure 2.2: Transfer theory describes relationships between the input and output images of an imaging system. In this illustration of a deterministic system, an image is transferred accurately except for a degradation in contrast.

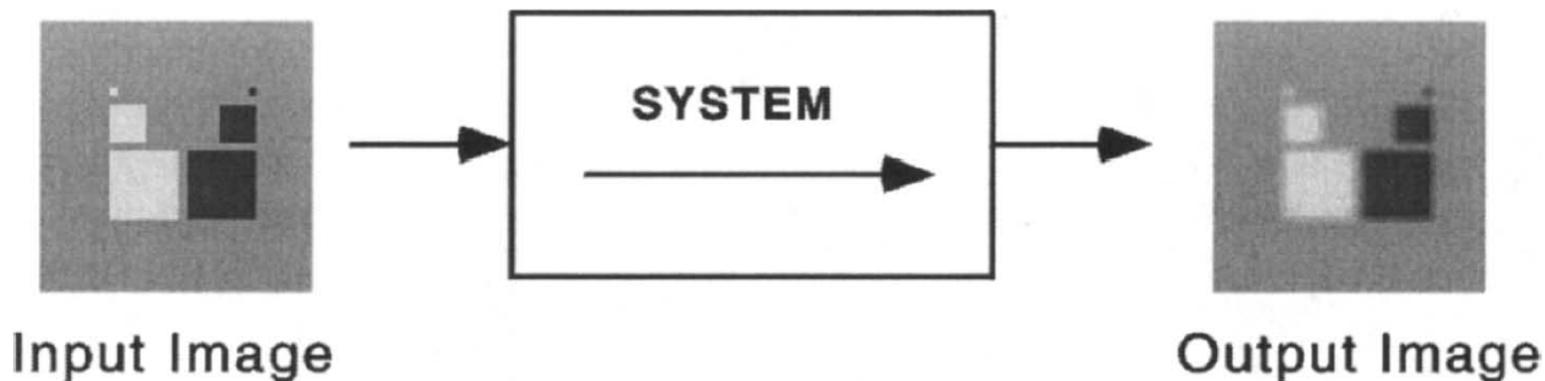


Figure 2.3: A system with poor spatial resolution transfers large-area contrast better than small-area contrast. As a result, the contrast of fine detail is reduced and the transferred image appears “blurred.”

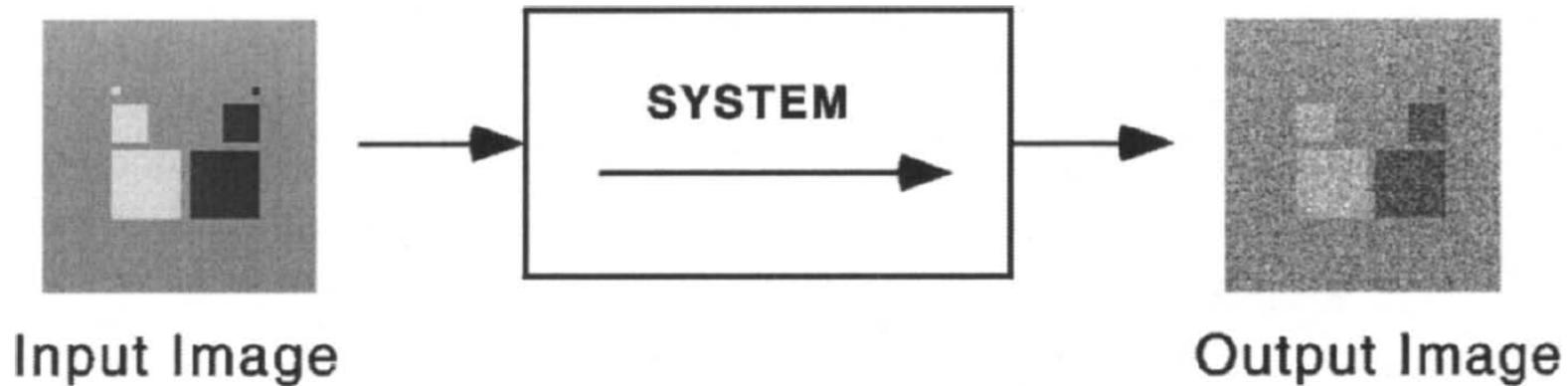


Figure 2.4: Noise in the output image is related to both the noise in the input image and the noise-transfer characteristics of the system. In this example, the image is transferred both with a reduction of image contrast and an increase in image-noise variance.

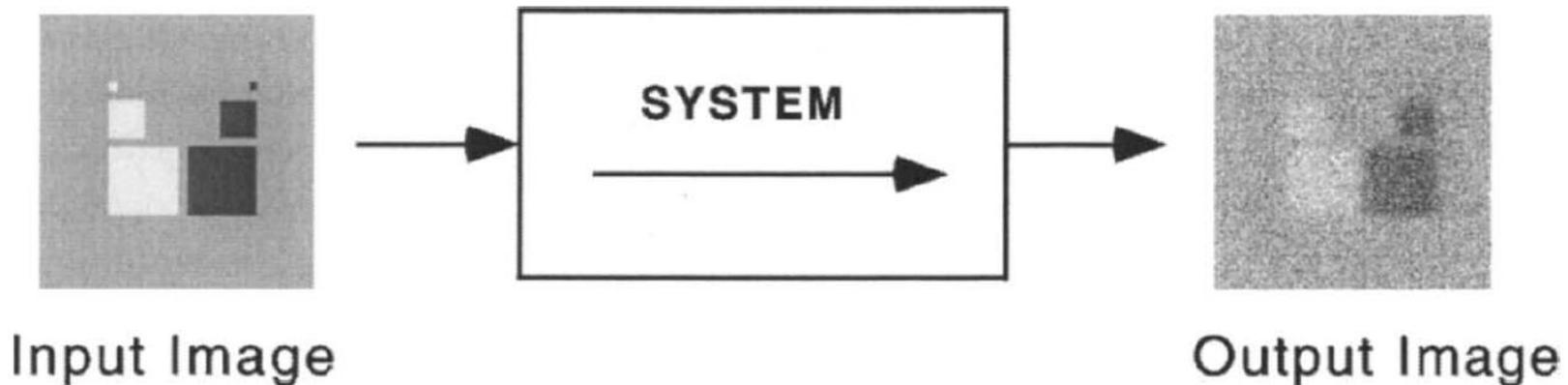


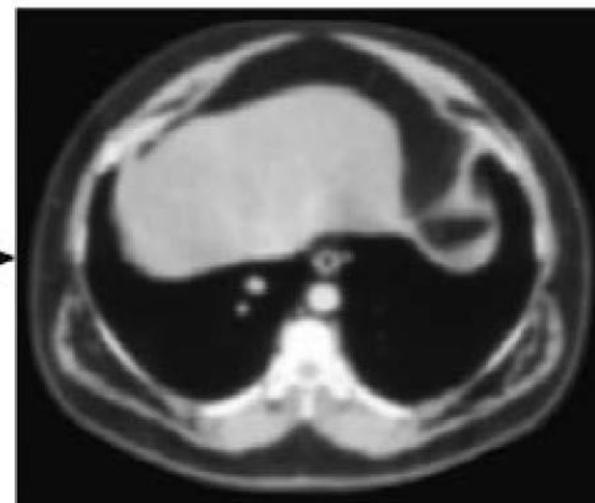
Figure 2.5: A system that degrades spatial resolution and also increases noise will severely compromise image quality as illustrated here, particularly for the visualization of small details.

Teoria de sistemas lineares

Scene: $f(x, y)$



Image: $g(x, y)$



Diagnostic Radiology Physics: A Handbook for Teachers and Students

$$g(x, y) = H\{f(x, y)\}$$

Função de
transferência
ou função
resposta

Funções
contínuas

Teoria de sistemas lineares

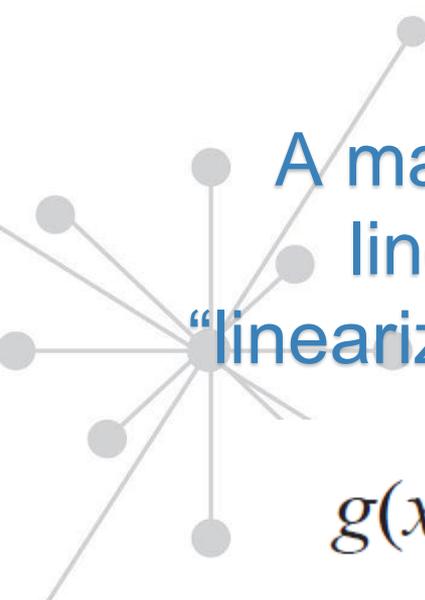
Propriedades:

- Linearidade

$$g_1(x, y) = H\{f_1(x, y)\}$$

$$g_2(x, y) = H\{f_2(x, y)\}$$

$$af_1(x, y)$$



A maior parte dos sistemas de imagem são lineares, aproximadamente lineares ou “linearizáveis” em uma pequena região de sinais

$$g(x, y) = \iint f(x', y')H(x, y, x', y') dx' dy'$$

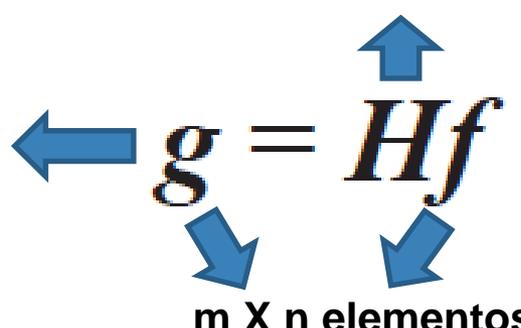
No caso de imagens digitais:

Soma ponderada, H ,
das fontes de sinais, f

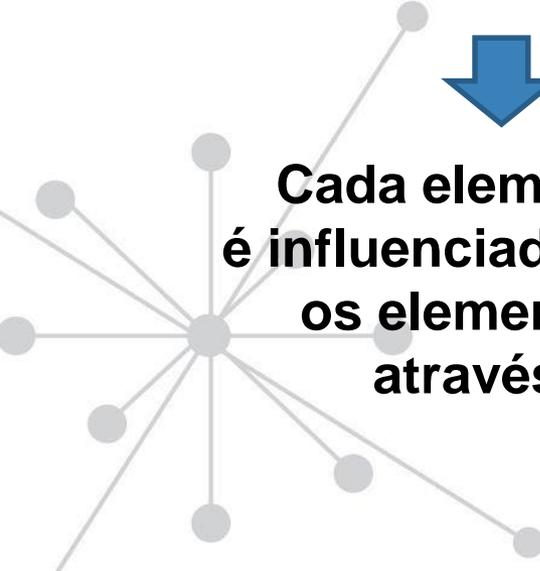
$$g = Hf$$

$(mn)^2$ elementos

$m \times n$ elementos

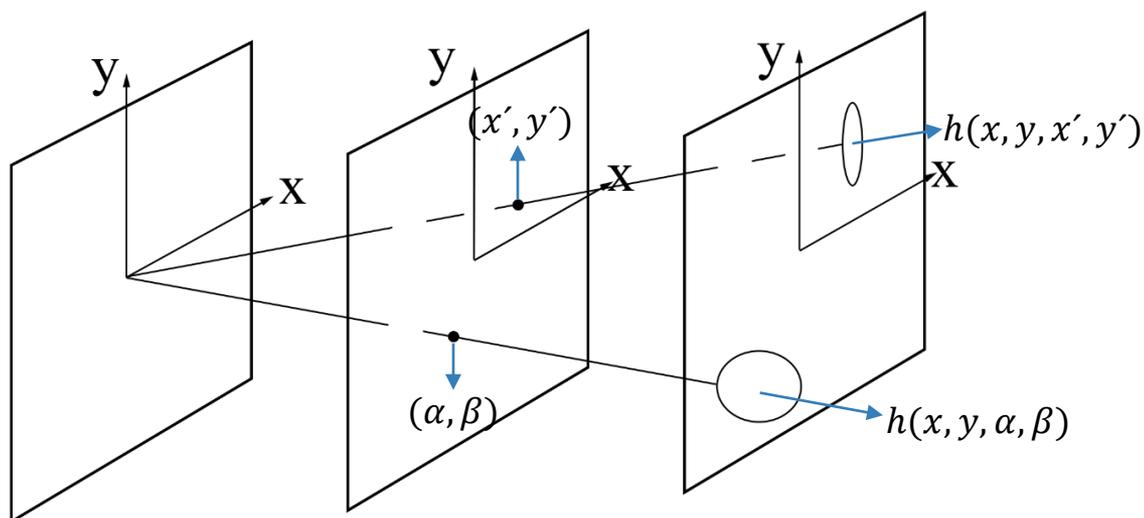


Cada elemento de g
é influenciado por todos
os elementos de f
através de H



Invariância no espaço ou espacialmente invariantes

- Um sistema é invariante no espaço se a função resposta, H , não varia em função da posição na imagem



$$g(x, y) = H[f(x', y')]$$

Plano da fonte

Plano do objeto

Plano do detector

Invariância espacial

$$g(x, y) = H \left[\int_{-\infty}^{\infty} \int_{-\infty}^{+\infty} f(x', y') \delta(x - x', y - y') dx' dy' \right]$$

$$g(x, y) = \int_{-\infty}^{\infty} \int_{-\infty}^{+\infty} f(x', y') \underbrace{H[\delta(x - x', y - y')]}_{h(x, y; x', y')} dx' dy'$$

$$g(x, y) = \int_{-\infty}^{\infty} \int_{-\infty}^{+\infty} f(x', y') h(x, y; x', y') dx' dy'$$

$$g(x, y) = \int_{-\infty}^{\infty} \int_{-\infty}^{+\infty} f(x', y') h(x - x', y - y') dx' dy' = f(x, y) \otimes \otimes h(x, y)$$

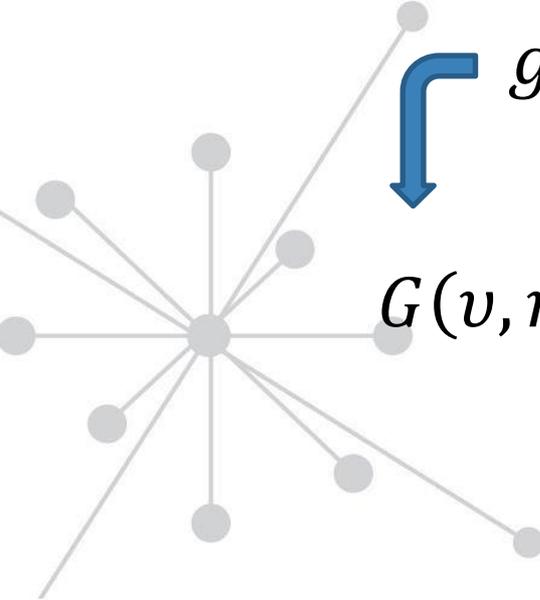
Invariância por deslocamento

$$F(v, \eta) = TF\{f(x, y)\}$$

$$H(v, \eta) = TF\{h(x, y)\}$$

$$G(v, \eta) = TF\{g(x, y)\}$$

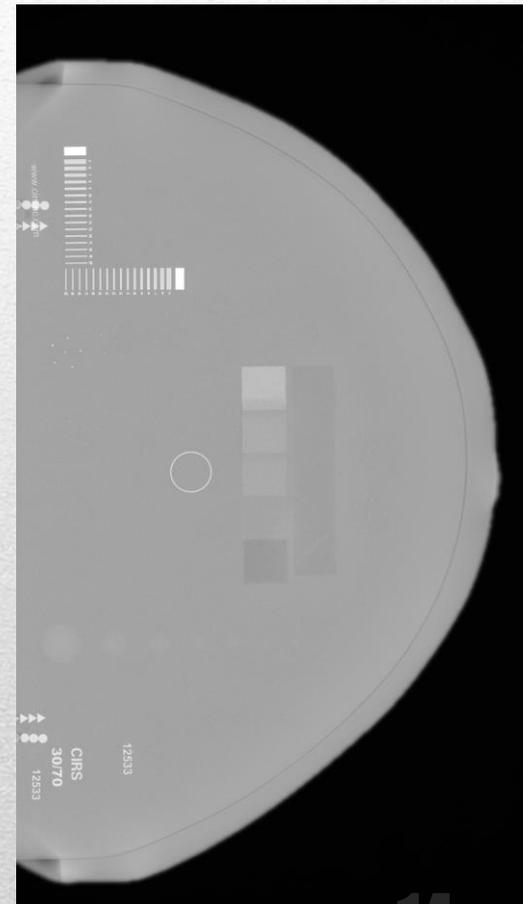
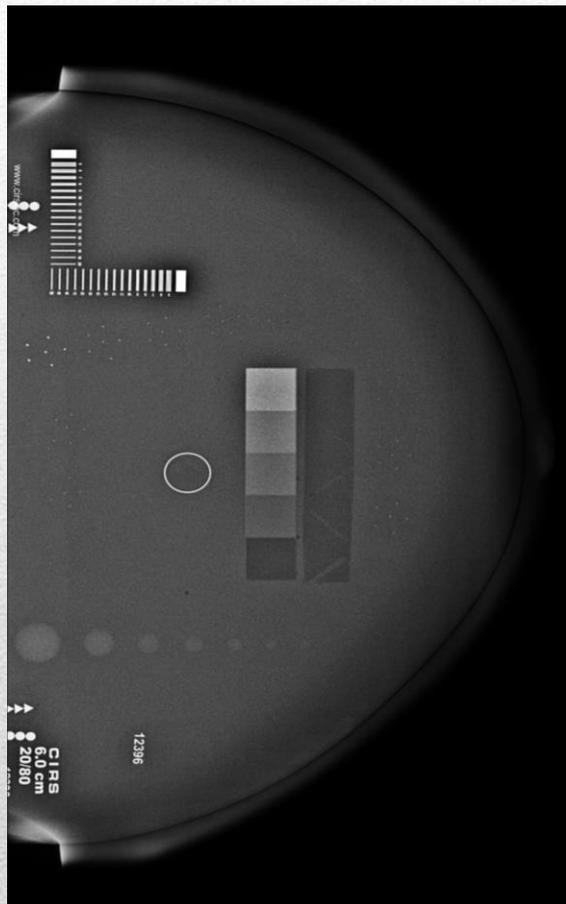
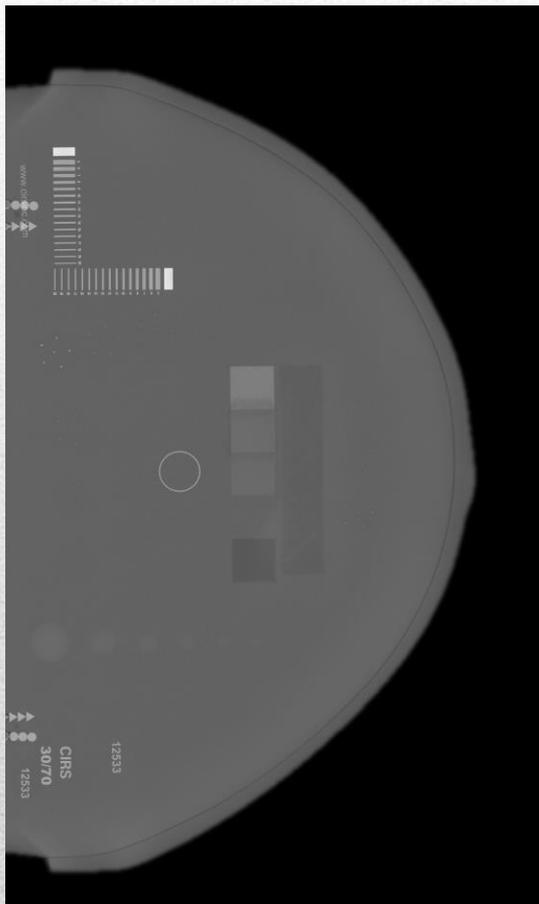

$$g(x, y) = f(x, y) \otimes \otimes h(x, y)$$


$$G(v, \eta) = F(v, \eta)H(v, \eta) \Rightarrow \mathbf{G} = \mathbf{FH}$$

Qualidade da imagem

- Avaliação subjetiva
 - Típica em artes visuais
- Imagens médicas
 - Informações específicas: anatomia ou funcionalidade
 - Qualidade
 - Métodos quantitativos
 - Busca da melhor relação custo-benefício
- Fatores inter-dependentes
 - Contraste
 - Resolução espacial
 - Ruído

What is the best image?



How is a high quality image?

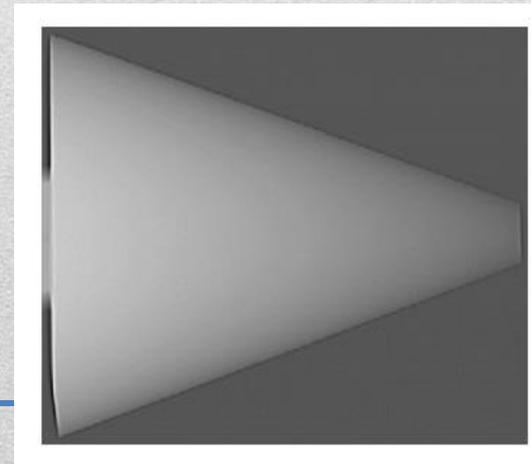
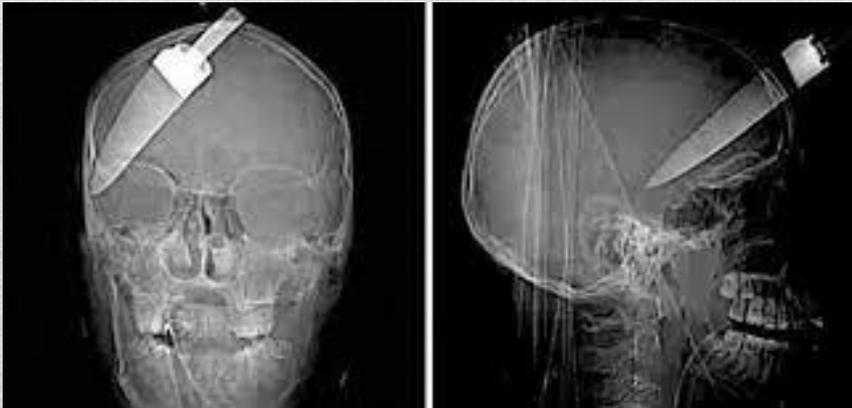
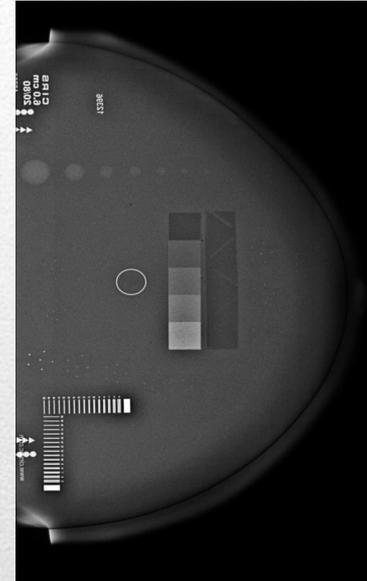
FIDELITY

Structures
with similar
properties

Small size
structures

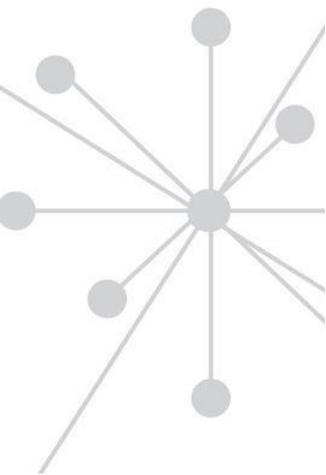
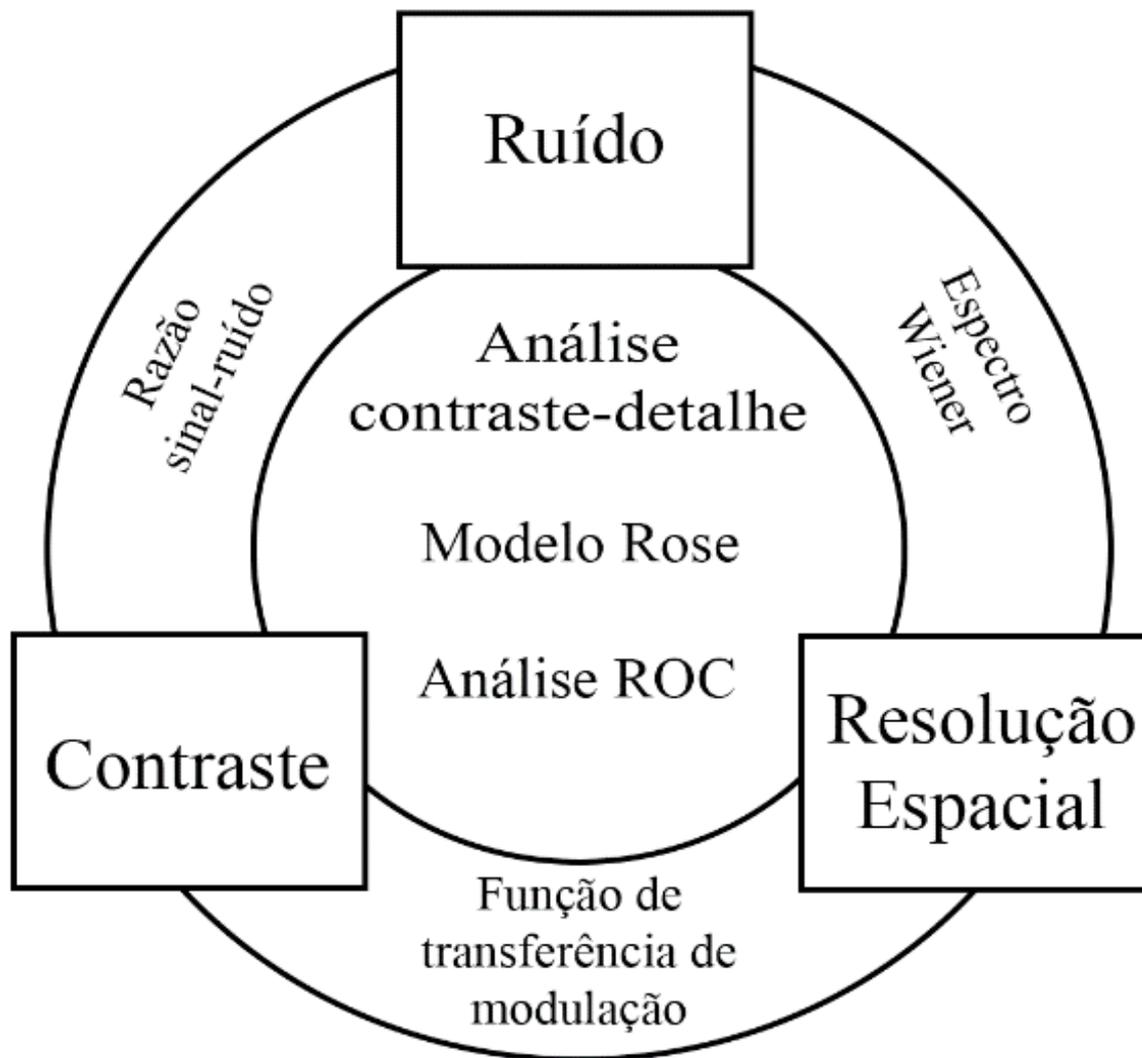
Small statistic
fluctuation

Clinical x Phantom images



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Qualidade de imagens





- Medida da magnitude das diferenças no sinal medido entre as regiões fisicamente distintas no objeto sob imagem

- Contraste na imagem

- Contraste do sinal (objeto)
- Contraste do detector

$$C_I = C_S \times C_D$$

- Dependências

C_S

Energia da fonte e características físicas do objeto

C_D

Como o sinal proveniente do objeto é modificado e registrado

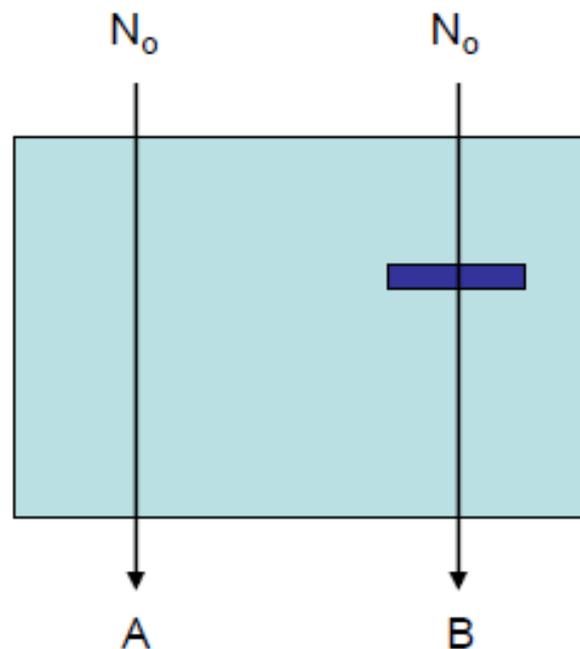
- Imagens digitais

- Ajustes no contraste → efeitos no ruído

Contraste do objeto

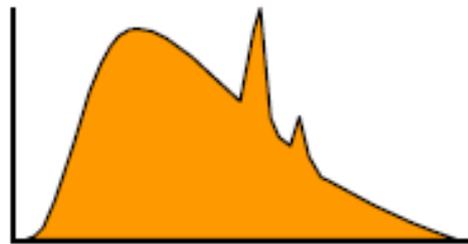
Subject Contrast

$$C = \frac{A - B}{A}$$

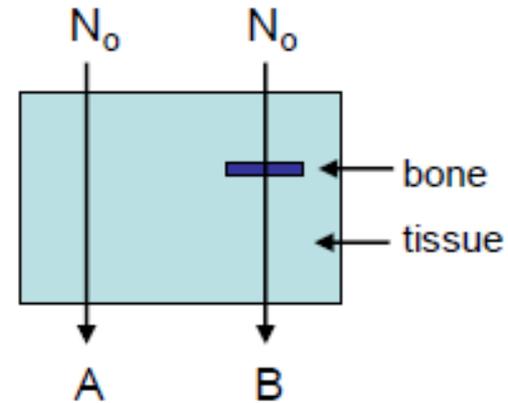


Contraste do objeto

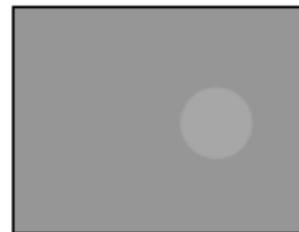
Subject Contrast



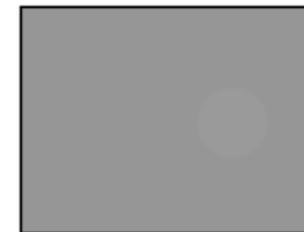
x-ray spectrum



low kVp



med kVp

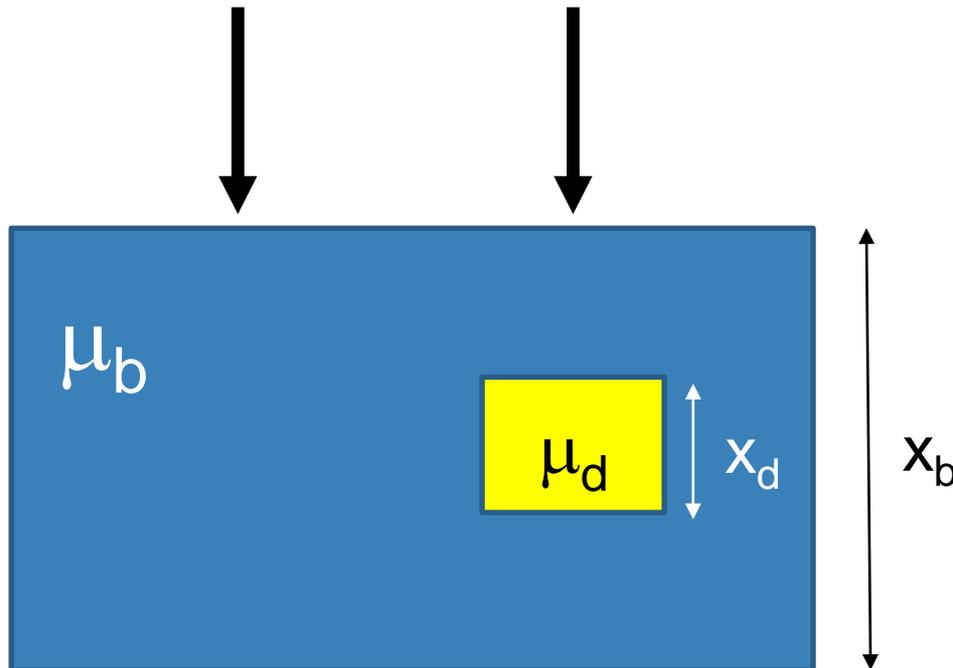


high kVp

bone contrast example

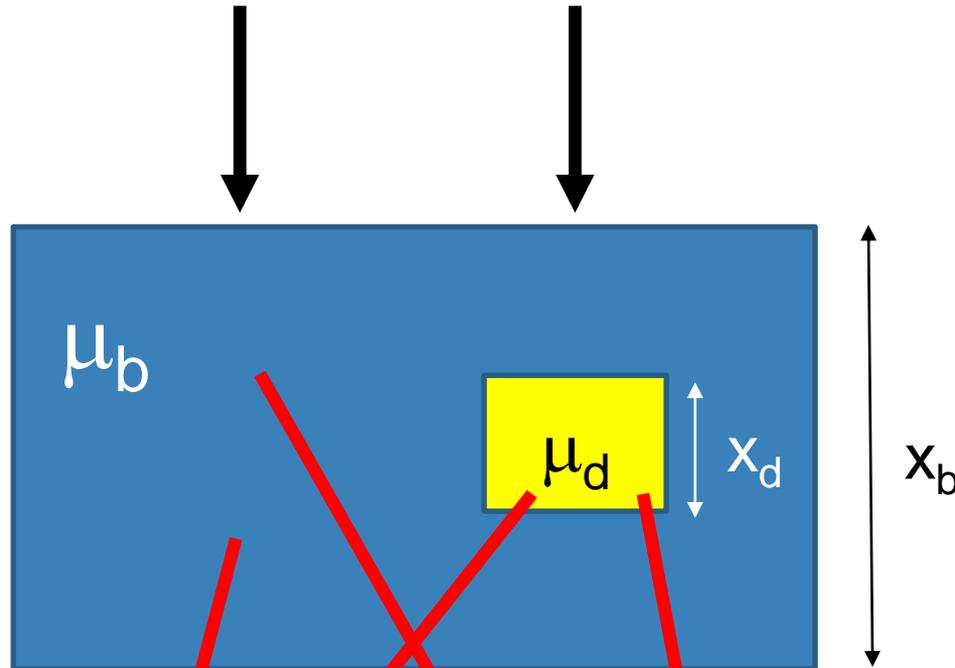
Contraste do objeto

contraste radiográfico
(feixe monocromático)



$$C_P = 1 - e^{-(\mu_d - \mu_b)x_d}$$

Contraste do objeto



$$C_P = 1 - e^{-(\mu_d - \mu_b)x_d} \frac{1}{1 + \text{SPR}}$$

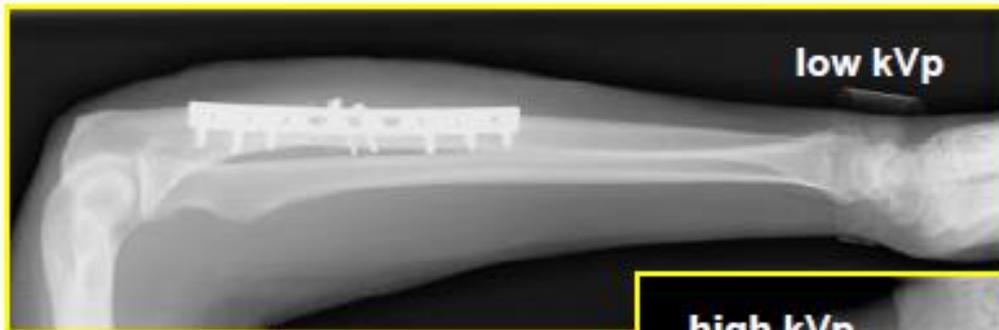
Agora considere o
Espalhamento

$$\text{SF} = E_s / (E_p + E_s)$$

$$\text{SPR} = E_s / E_p$$

$$\text{SF} = ((\text{SPR}^{-1}) + 1)^{-1}$$

Contraste do objeto



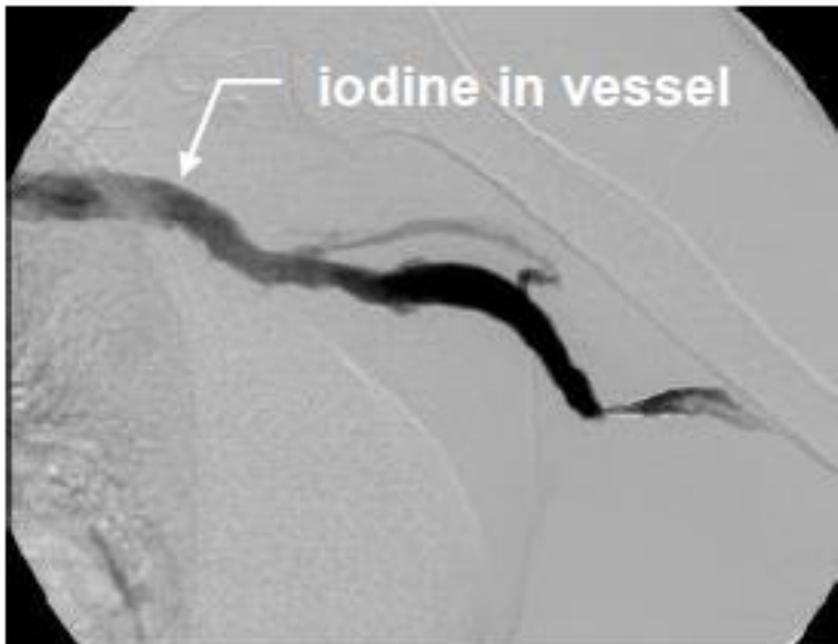
↑
good bone contrast



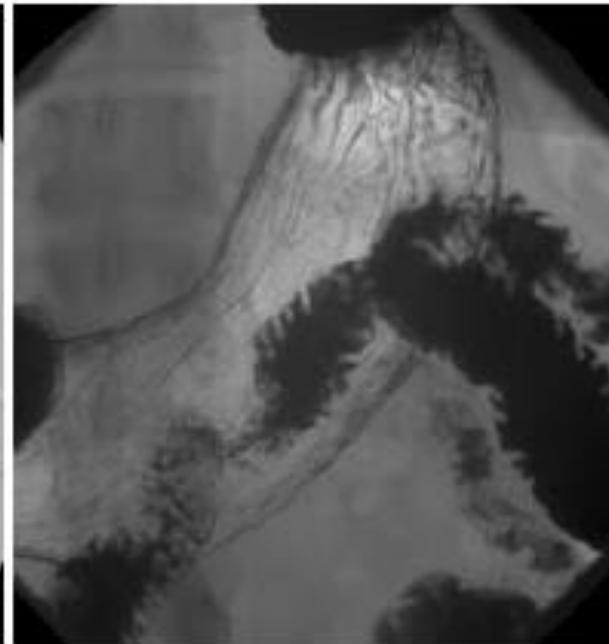
→
good lung contrast

Subject Contrast

contrast agents (obviously) affect contrast

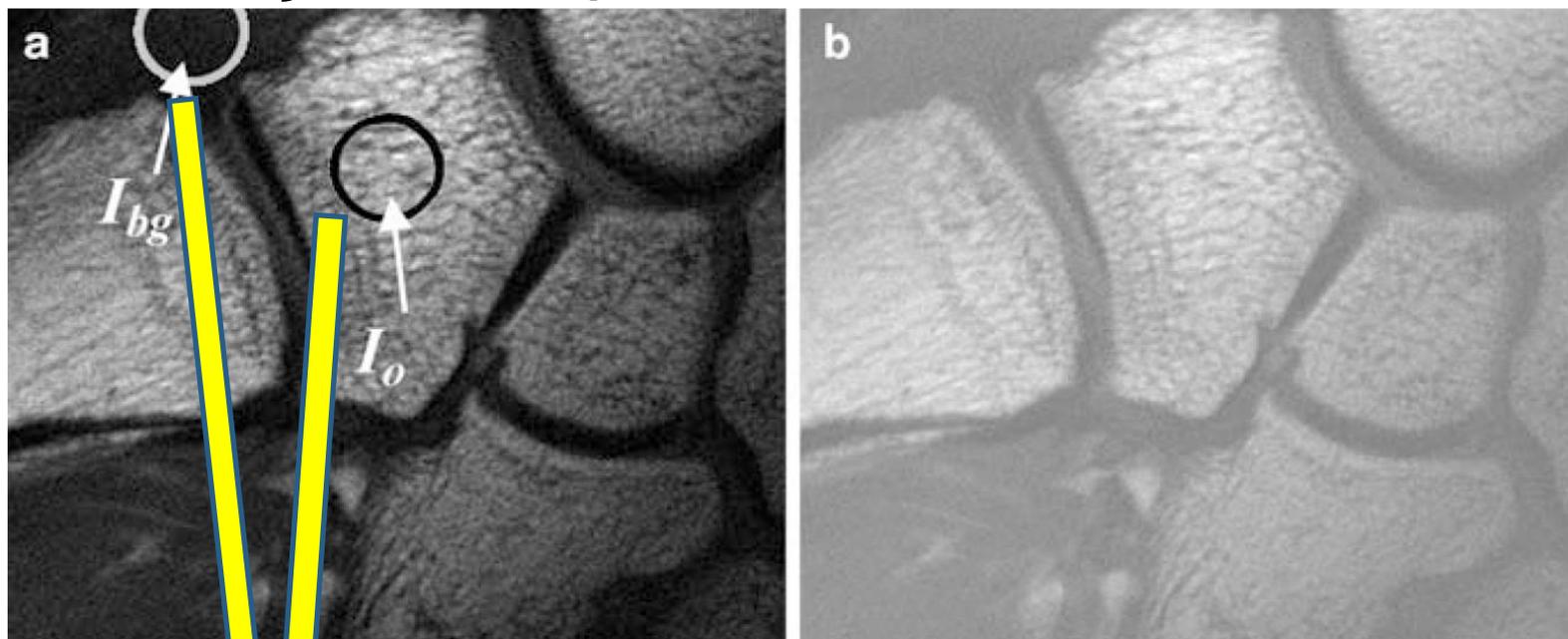


digital subtraction angiography with
iodine contrast agent in vessel



double contrast GI study

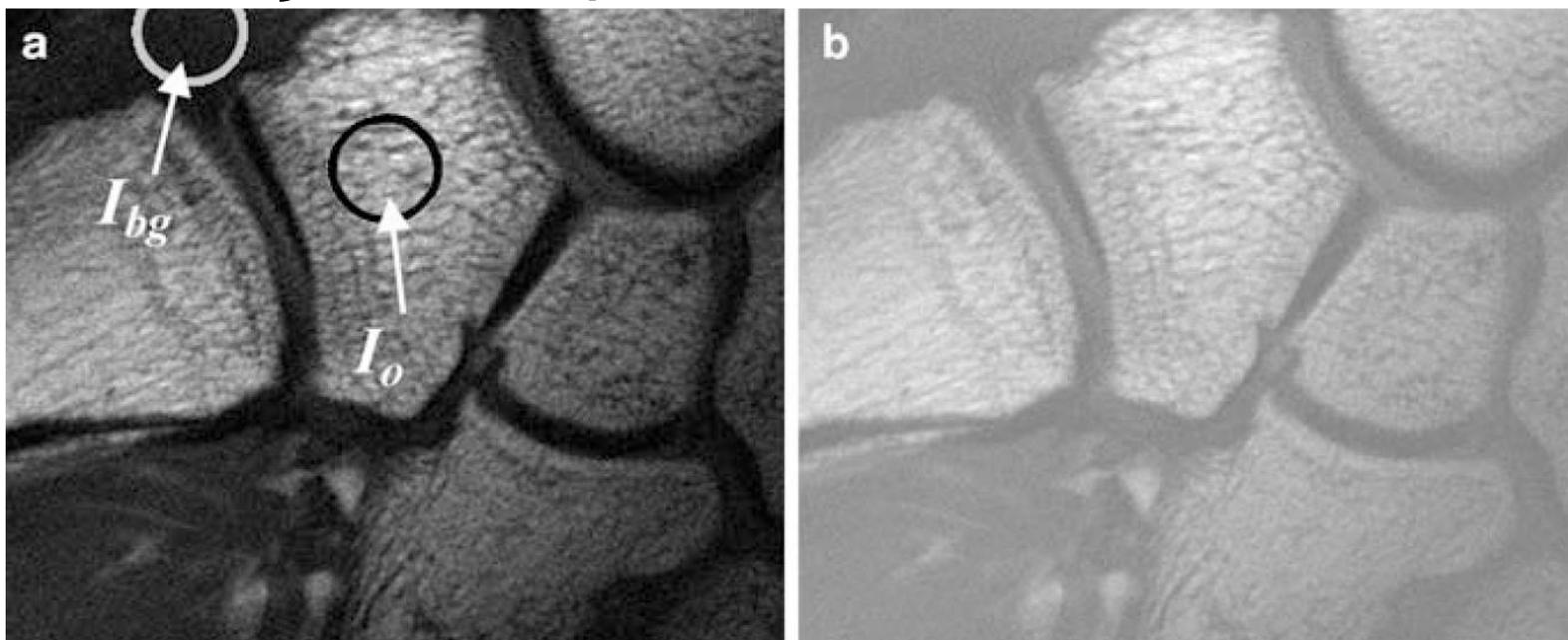
- Medições simples do contraste



subjetividade

$$C = \frac{I_o - I_{bg}}{I_{bg}} \left\{ \begin{array}{l} = 3,35 - \text{imagem a} \\ = 7,6 X \\ = 0,44 - \text{imagem b} \end{array} \right.$$

- Medições simples do contraste

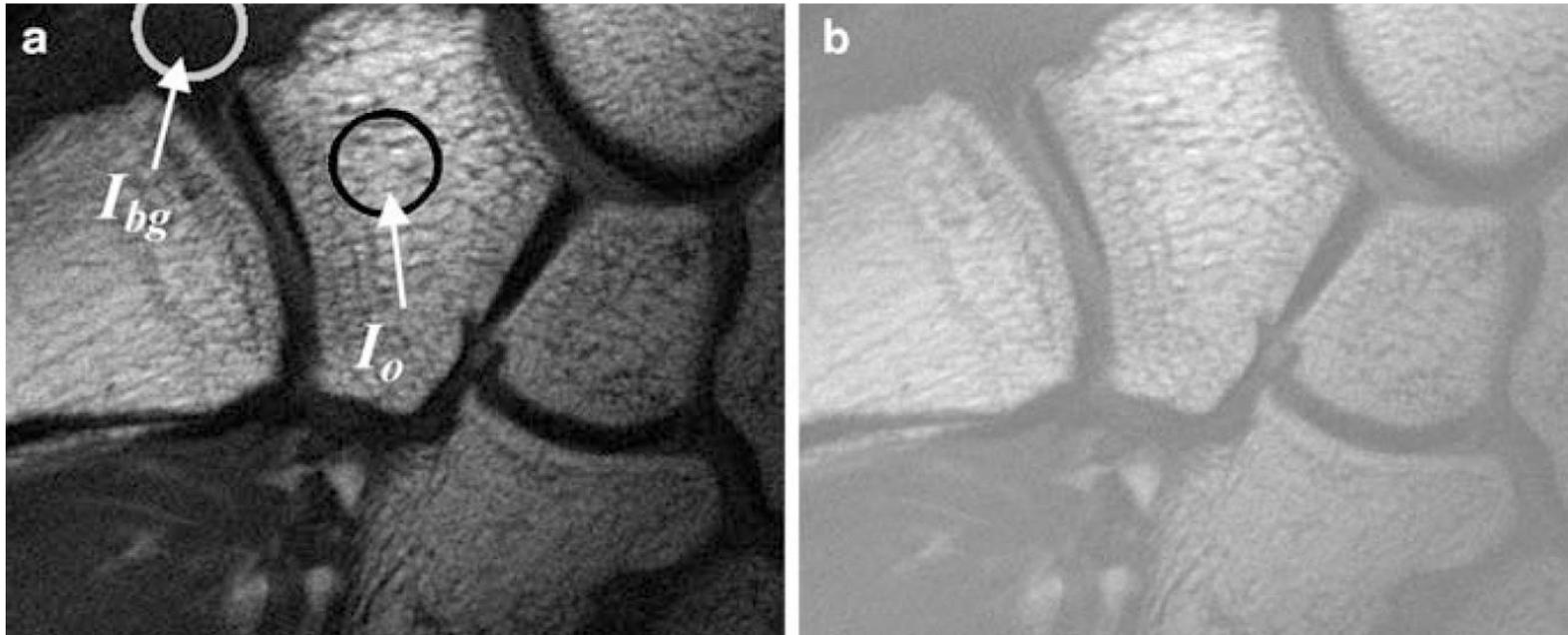


$$C = \frac{I_o - I_{bg}}{I_o + I_{bg}}$$

≈ percepção visual

$\left\{ \begin{array}{l} = 0,63 - \text{imagem a} \\ \mathbf{3,5 X} \\ = 0,18 - \text{imagem b} \end{array} \right.$

- Medições simples do contraste



$$C = \log_{10} \frac{I_o}{I_{bg}}$$

≈ percepção visual

$$\left\{ \begin{array}{l} = 0,62 - \text{imagem a} \\ \mathbf{3,9 X} \\ = 0,16 - \text{imagem b} \end{array} \right.$$

Qualidade das imagens

Resolução de contraste

Contraste

Objeto (*subjective*)

Detector

Digital

Estatístico

Ruído

Eletrônico

Erros de quantização

Resolução espacial

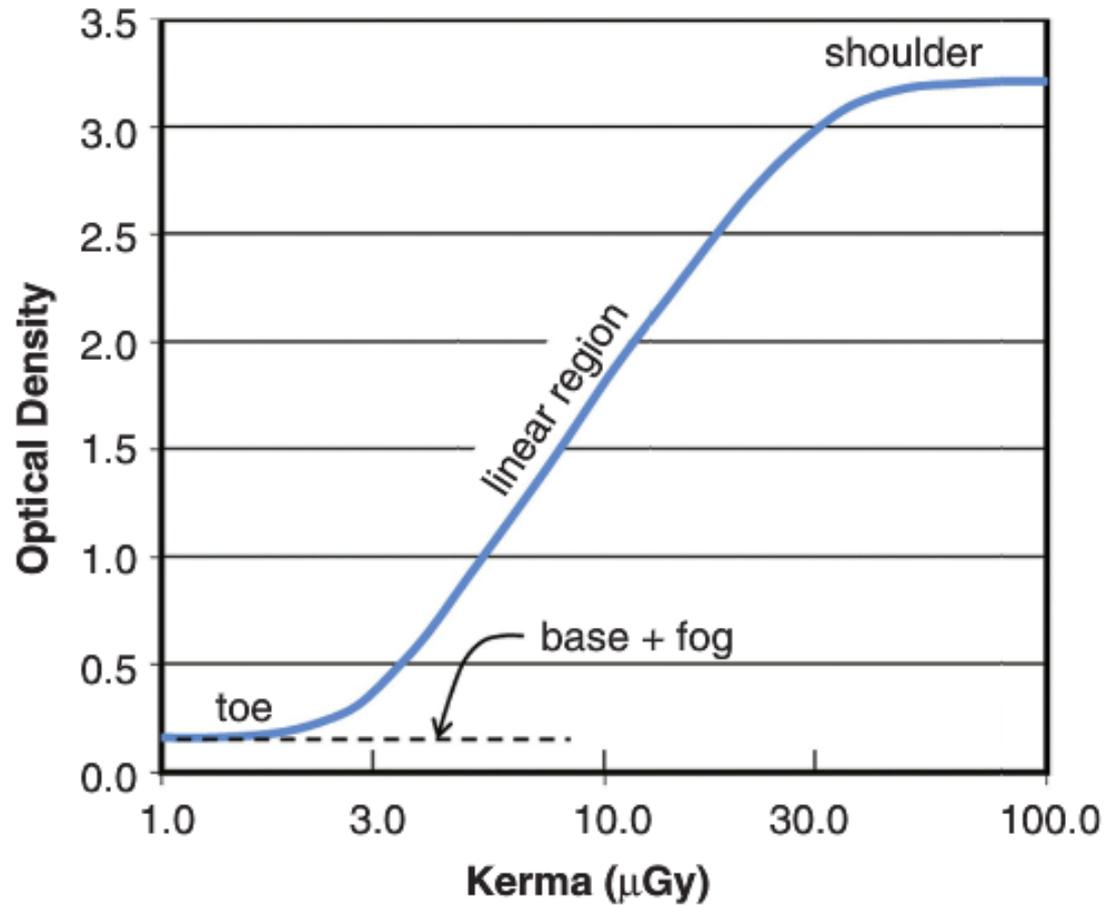
Funções de entrada

Amostragem digital

Contraste/detalhe

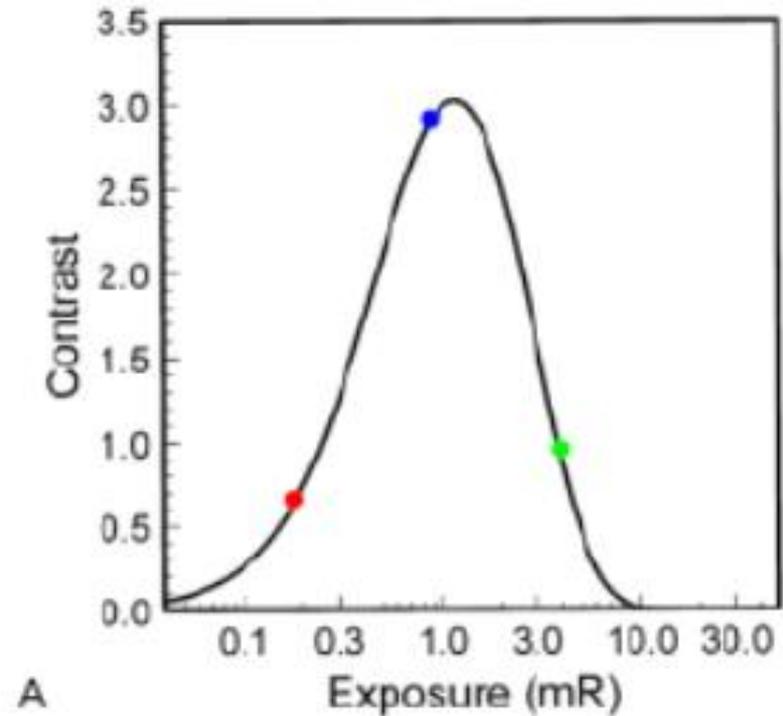
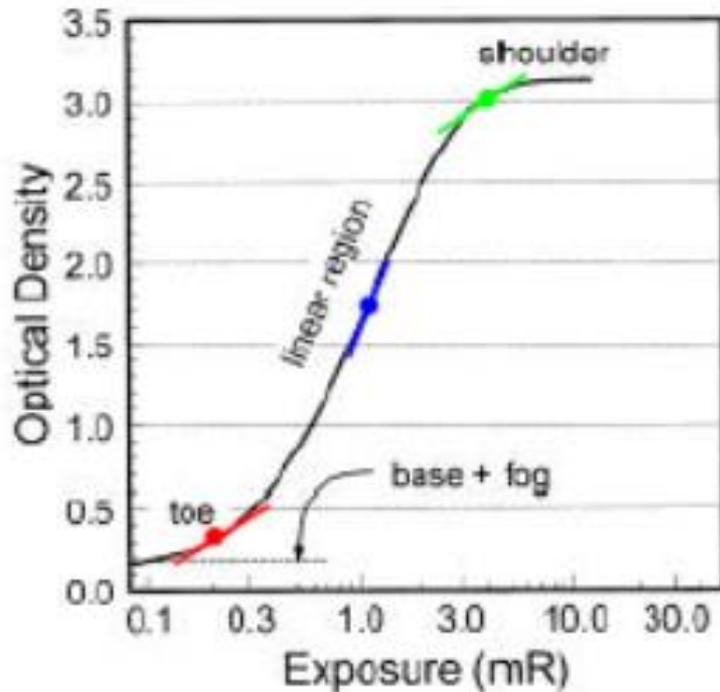


Contraste do detector



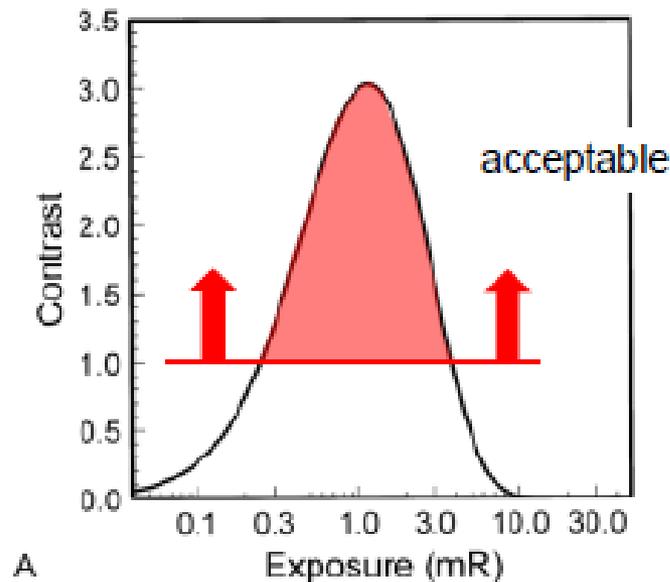
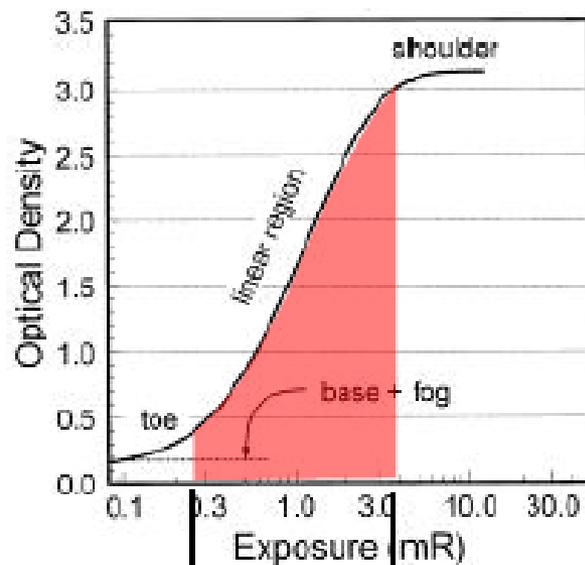
Contraste do detector

Detector contrast (screen film)



Contraste do detector

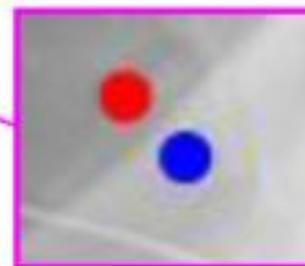
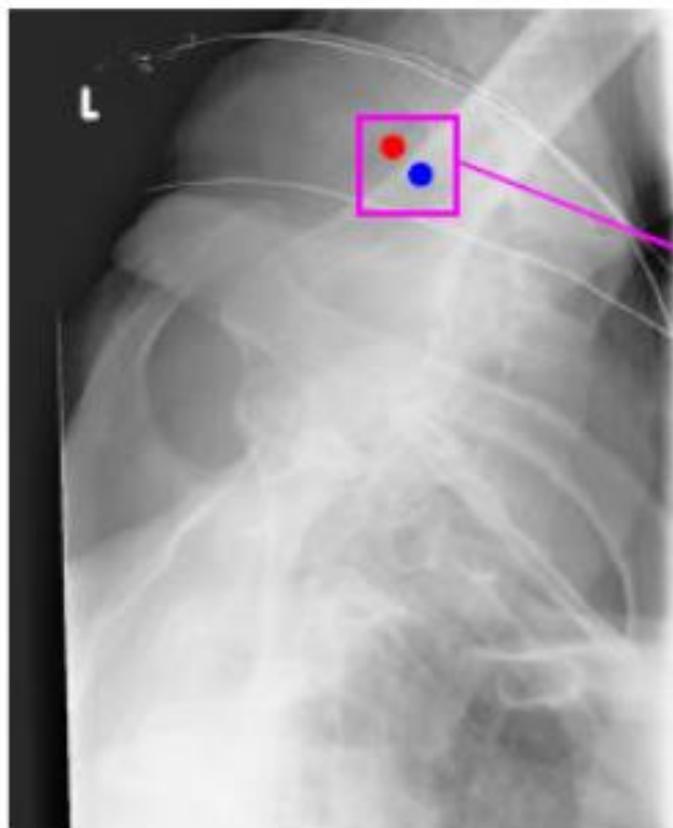
Detector contrast (screen film)



latitude

Contraste do detector

Radiographic contrast (screen film)



$$OD_1 - OD_2 = \text{radiographic contrast}$$

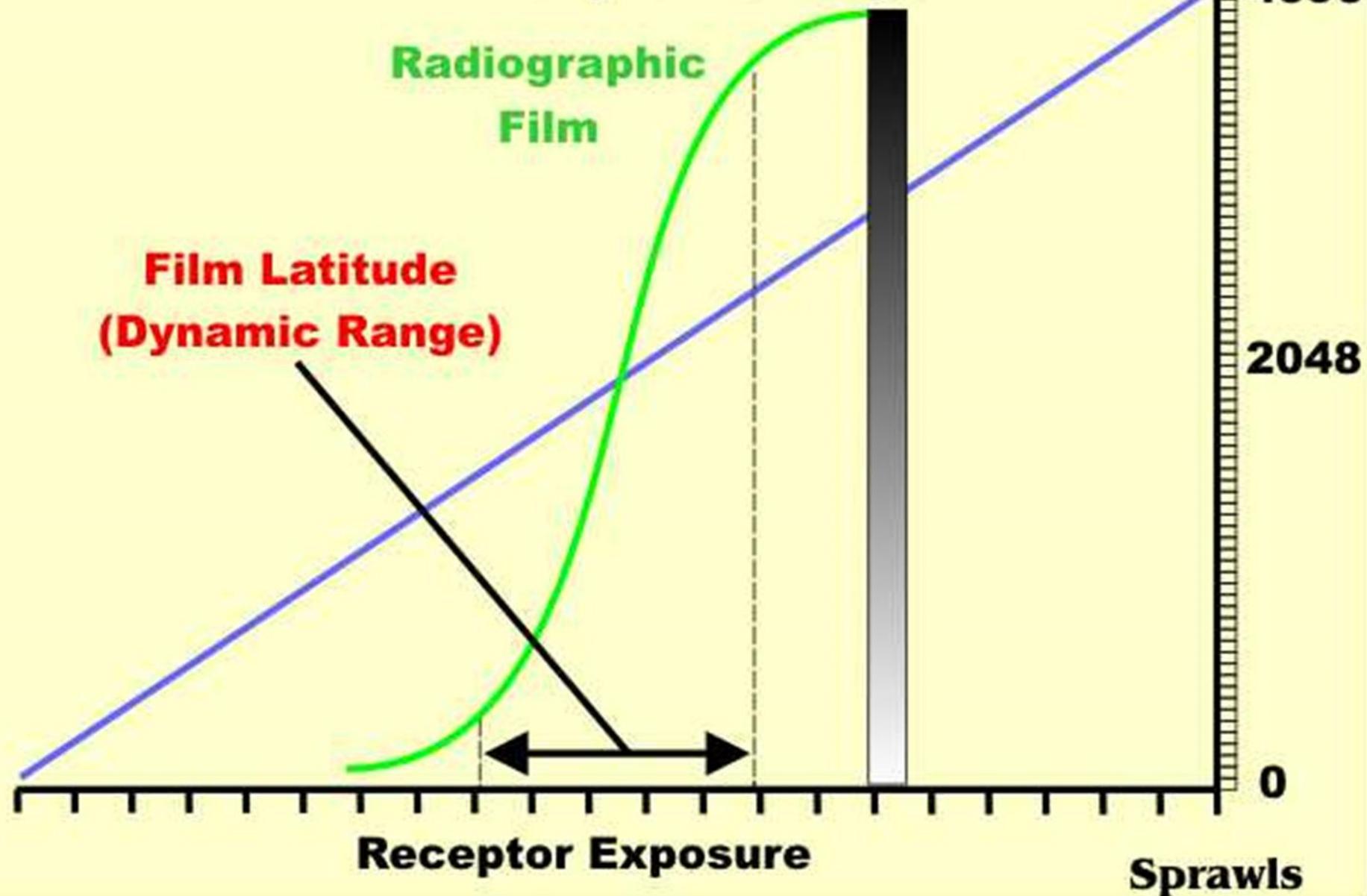
screen film radiography

Pixel Values

12 Bit Dynamic Range

Radiographic
Film

Film Latitude
(Dynamic Range)



Film Density

Radiographic
Film

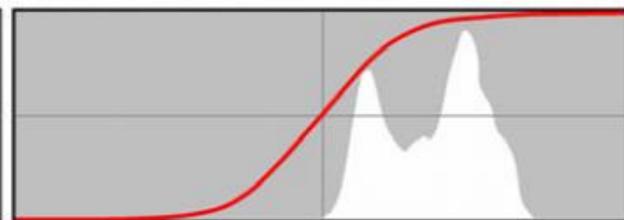
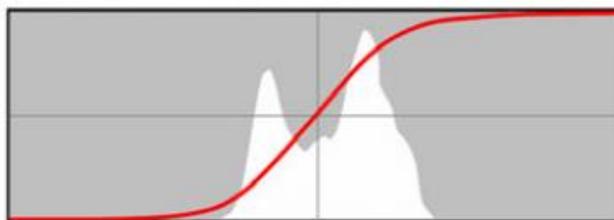
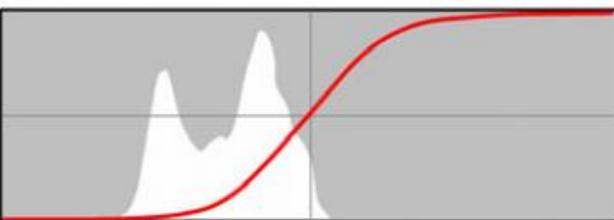
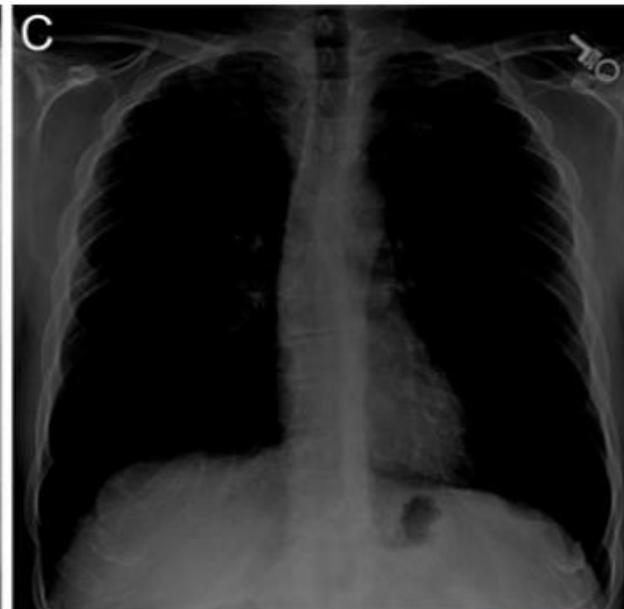
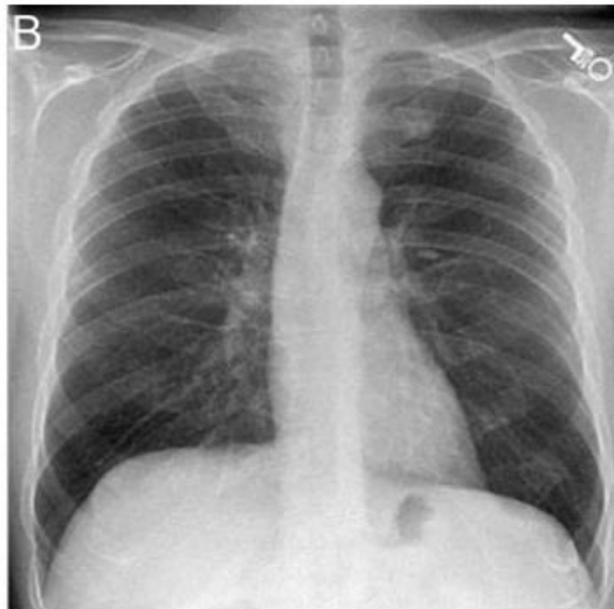
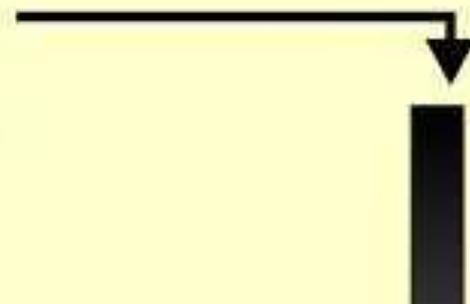
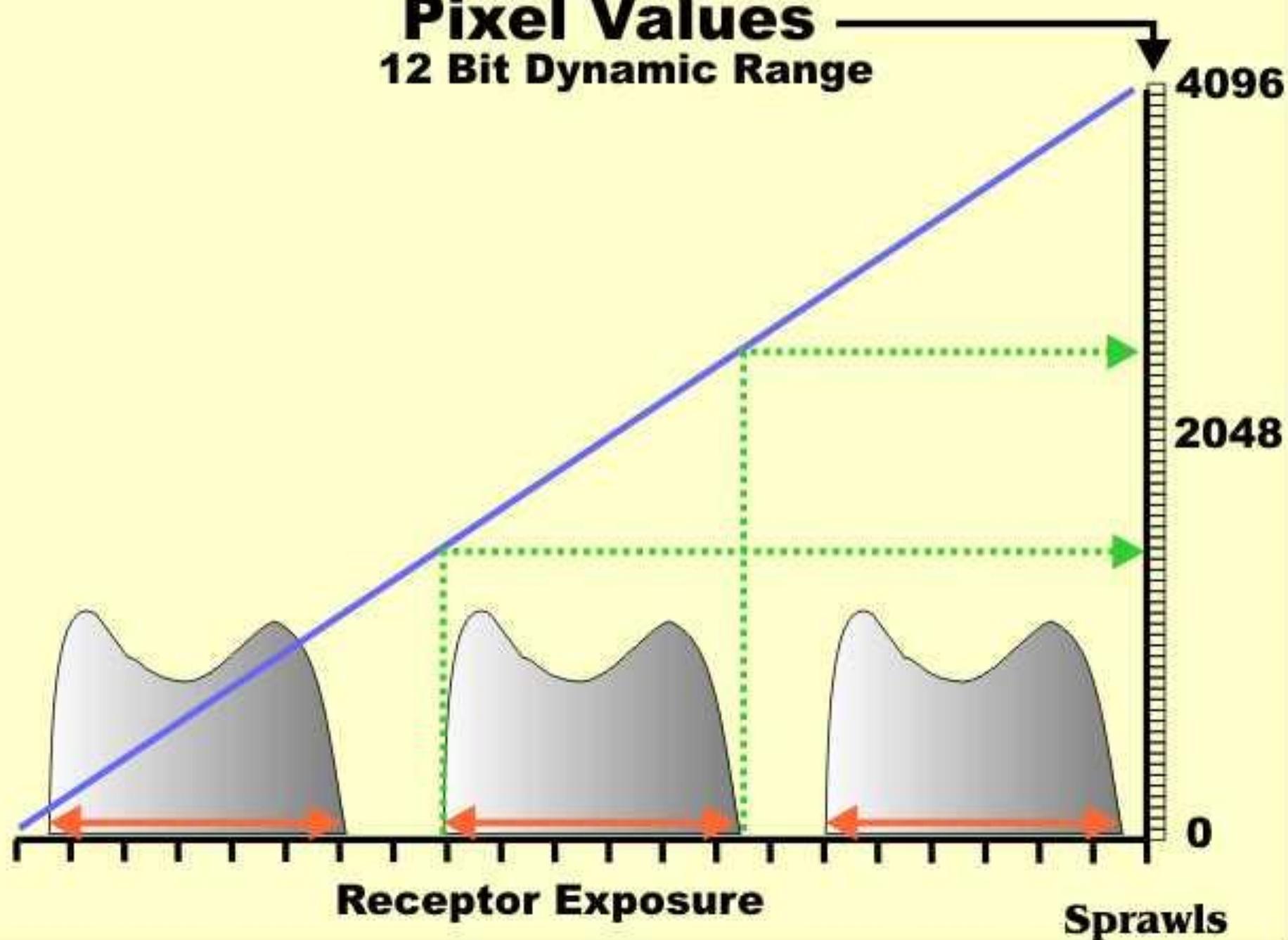


Fig. 1 Shown are the responses of a screen-film detector with a fixed radiographic speed to (a) underexposure, (b) correct exposure and (c) overexposure. Underneath each image is a histogram representing the intensity of X-rays transmitted through the patient. The x-axis

represents transmitted exposure intensity and the y-axis represents magnitude. The s-shape line is the characteristic curve that translates exposure intensity into optical density on the processed film. Note that this curve does not change position along the exposure axis

Pixel Values

12 Bit Dynamic Range



Qualidade das imagens

Resolução de contraste

Contraste

Objeto (*subjective*)

Detector

Digital

Estatístico

Ruído

Eletrônico

Erros de quantização

Resolução espacial

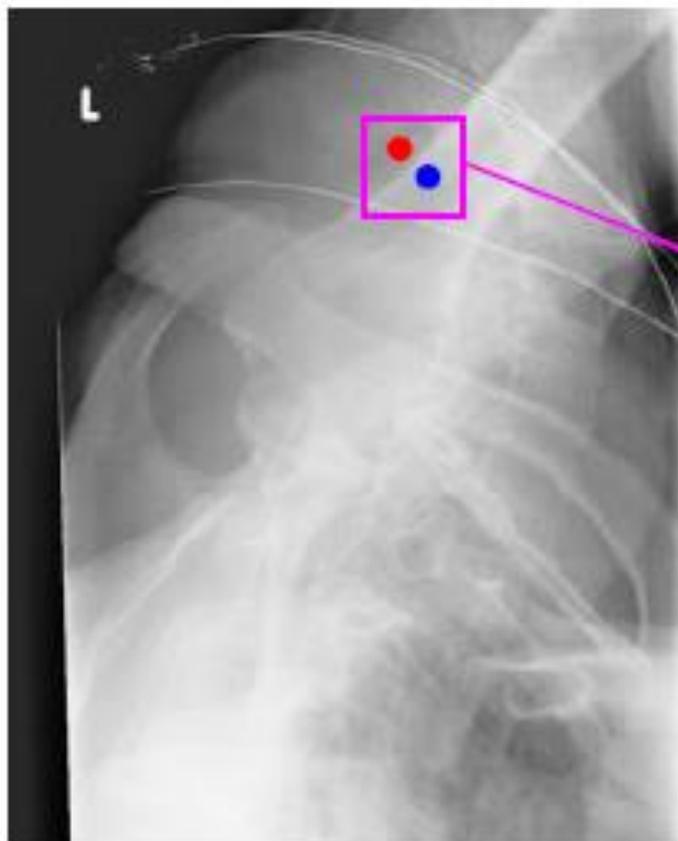
Funções de entrada

Amostragem digital

Contraste/detalhe



Detector contrast (digital)

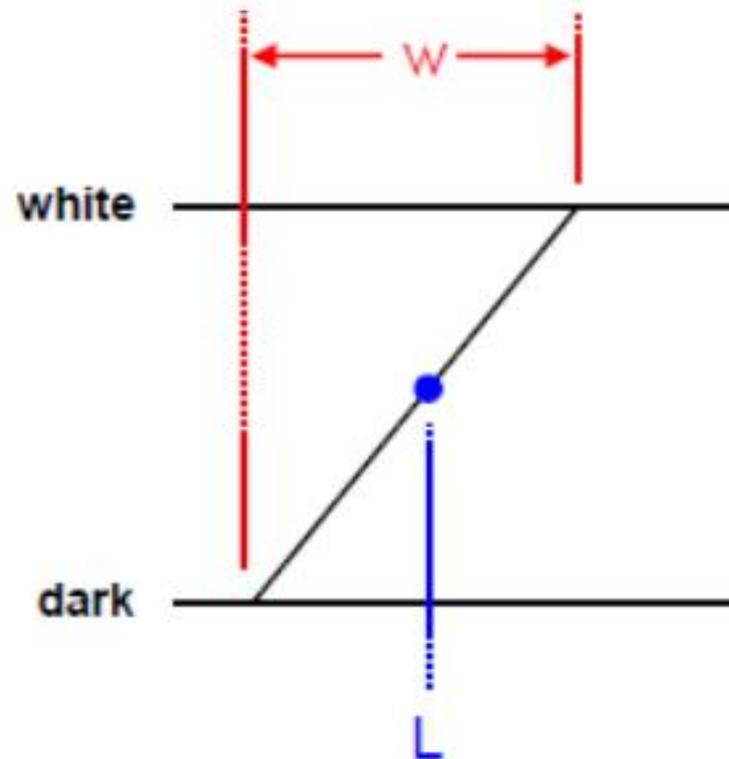
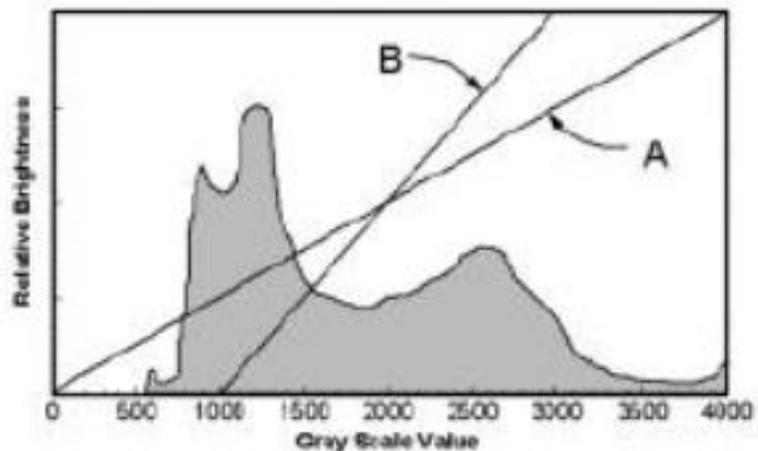
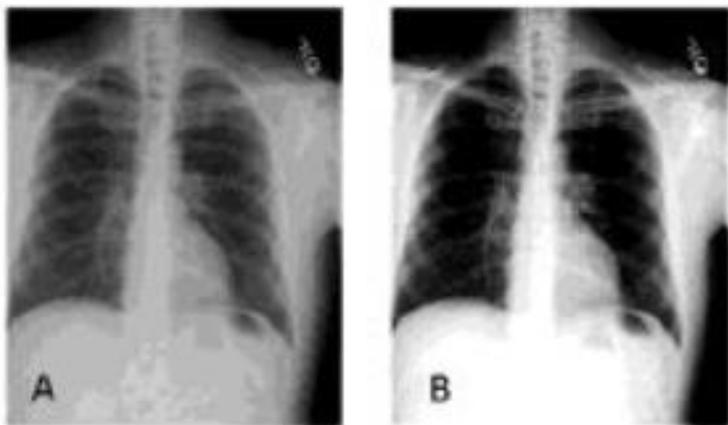


$$\frac{GS - GS}{GS} = \text{contrast}$$

digital radiography

Contraste digital

Manipulação digital do contraste - Nível e janela

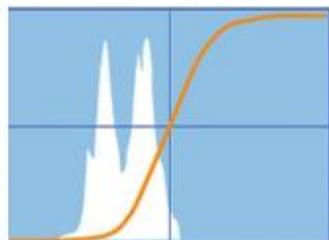


Contraste digital

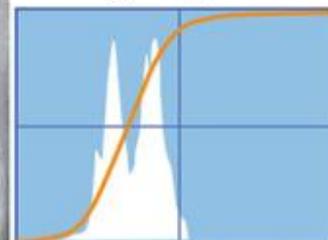
Fixed Speed ← Screen-Film

Digital → Variable Speed

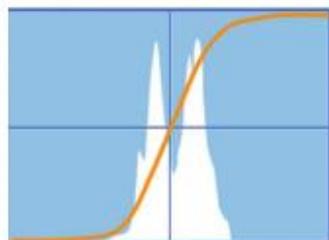
under exposure



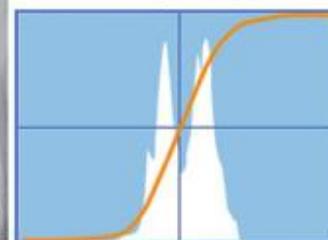
high speed



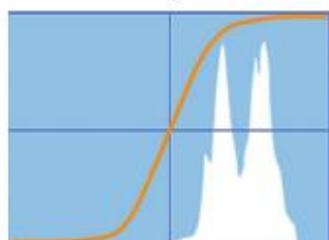
proper exposure



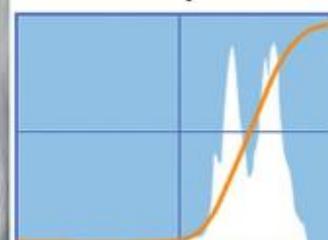
average speed



over exposure



low speed



Exposure distribution

Resultant Images

Histogram distribution

Contraste digital



Bone (W=2000, L=300)



Lung (W=2000, L= -700)

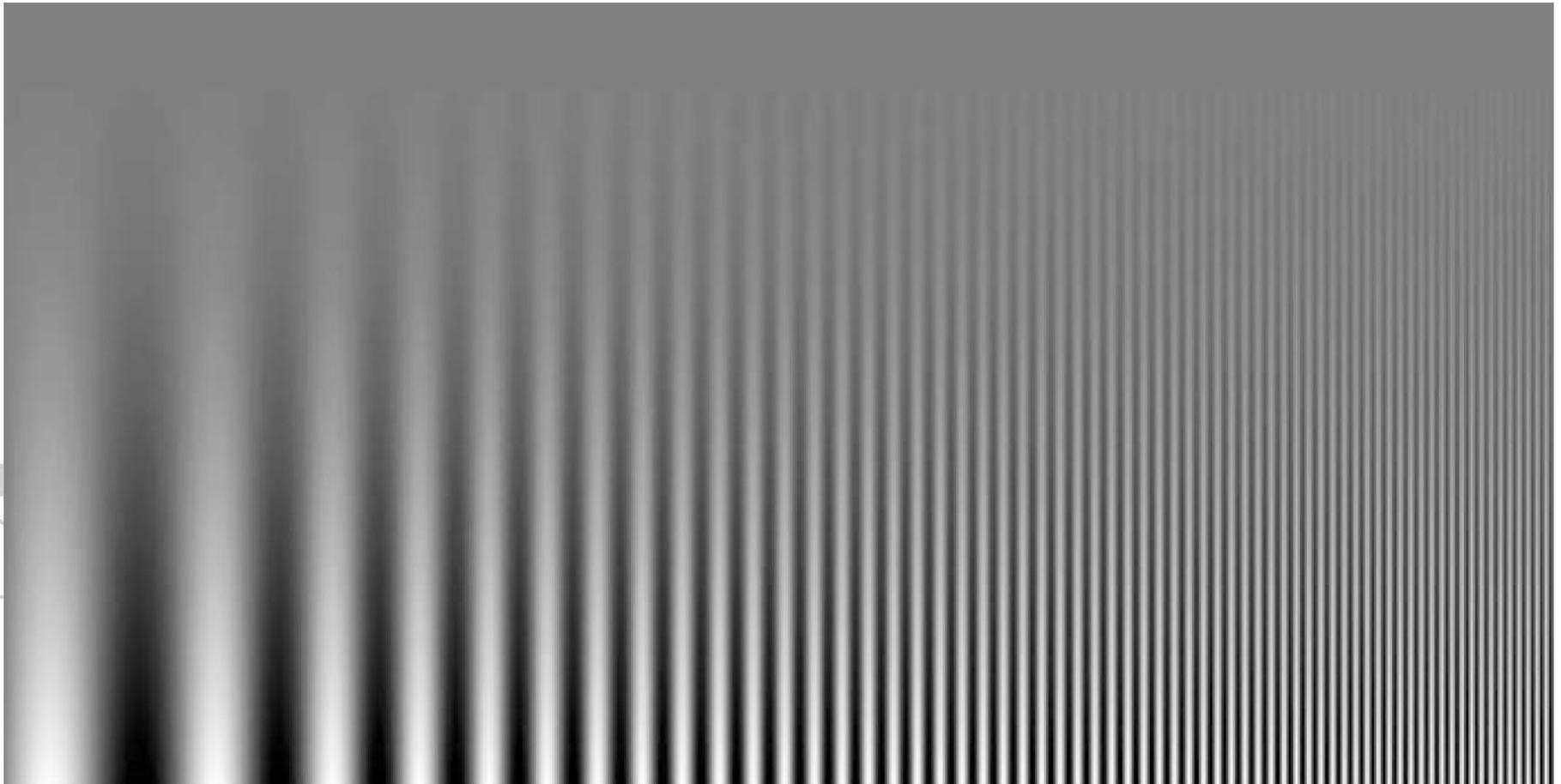


Abdominal (W=400, L=80)

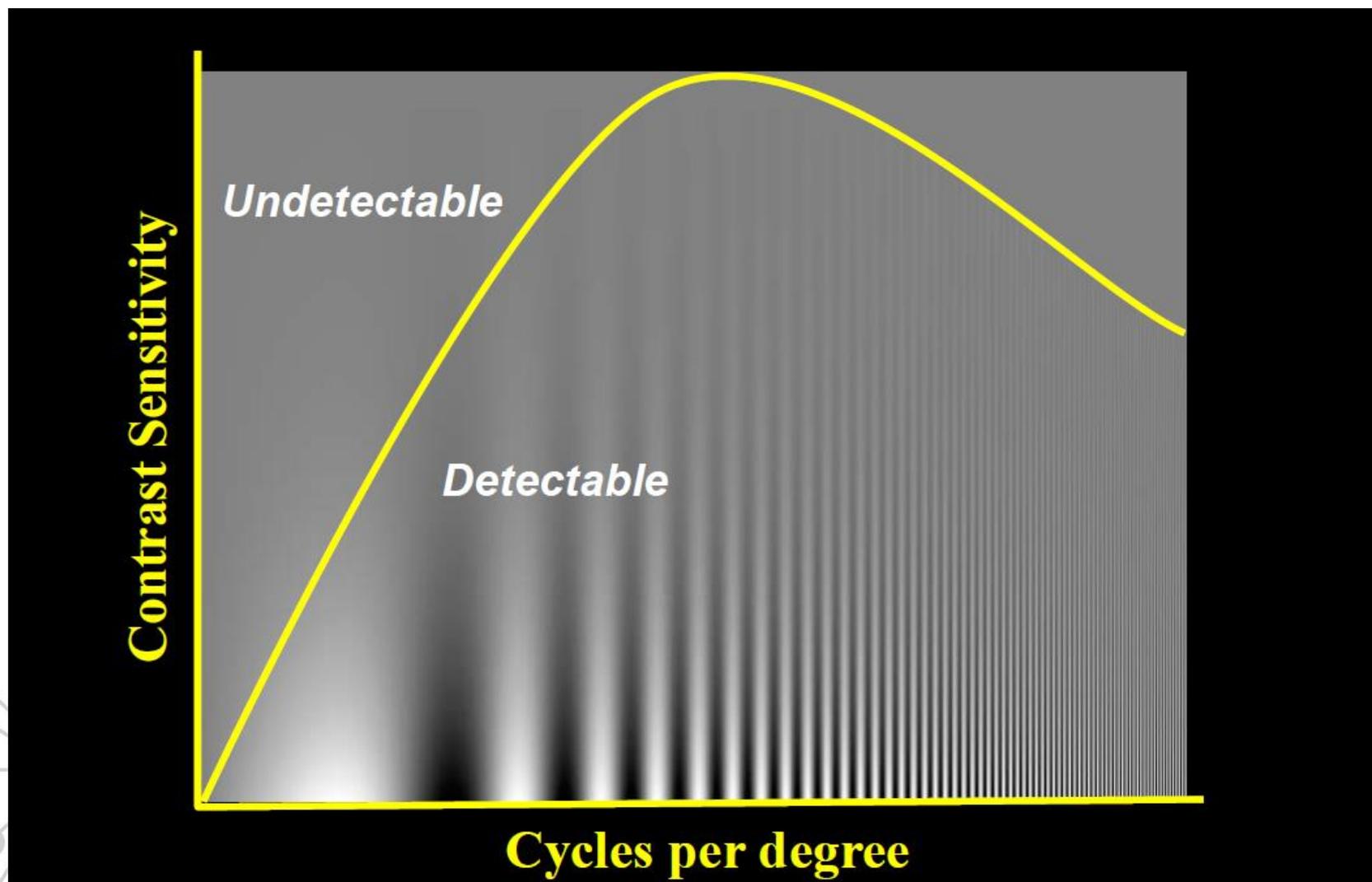
same image:
different window and level
settings

Contraste e frequência espacial

- Percepção humana do contraste depende da frequência espacial

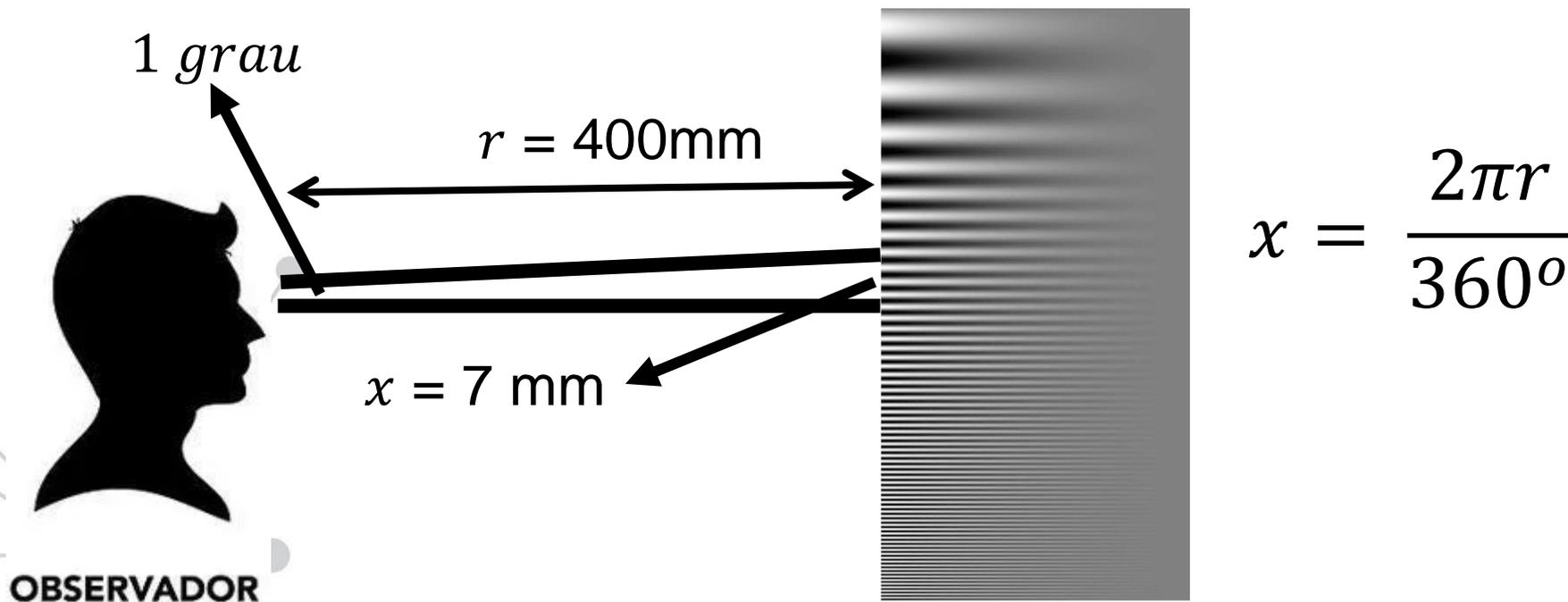


Contraste e frequência espacial



Contraste e frequência espacial

- Padrão senoidal \rightarrow 3 ciclos/grau
Grau \rightarrow ângulo no campo visual



3 ciclos/grau \rightarrow 1 ciclo/2,33mm

Which factors influencing contrast?

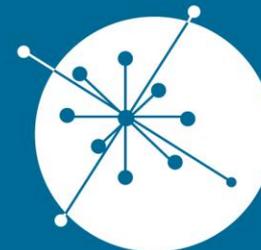
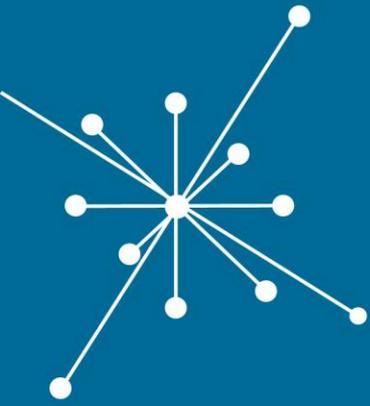
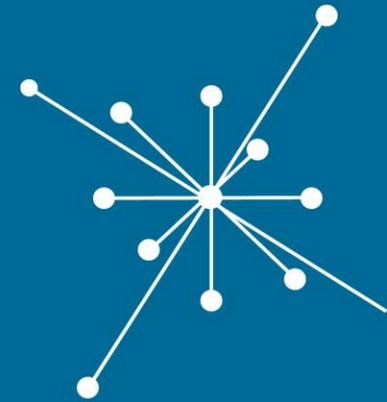
- **Radiographic or subject contrast**

- Tissue thickness
- Tissue density
- Tissue electron density
- Effective atomic number Z
- X Ray energy
- X Ray spectrum (filter)
- Scatter rejection
 - Grid
- ...

- **Image contrast**

- The radiographic contrast plus :
- Film/screen and processing characteristics
- Windowing level of CR, DR, CT, and DSA
- ...

Vamos falar dos trabalhos?



GRUPO DE
**DOSIMETRIA
DAS RADIAÇÕES**
e FÍSICA MÉDICA

IFUSP - Instituto de Física da USP

TEMAS GERAIS PARA MONOGRAFIAS

- IMAGENS ESPECTRAIS/DUPLA ENERGIA EM CT
- APLICAÇÕES DE INTELIGENCIA ARTIFICIAL EM IMAGENS
- TECNICAS DE RECONSTRUÇÃO ITERATIVA
- **INOVAÇÕES EM TECNICAS DE PROCESSAMENTO E/OU RECONSTRUÇÃO DE IMAGENS EM MAMOGRAFIA/TOMOSINTESE – KRIZIA – VAI MANDAR DETALHAMENTO**
- INOVAÇÕES EM TECNICAS DE PROCESSAMENTO E/OU RECONSTRUÇÃO DE IMAGENS EM PET/CT
- INOVAÇÕES EM TECNICAS DE PROCESSAMENTO E/OU RECONSTRUÇÃO DE IMAGENS EM SPECT
- INOVAÇÕES EM TECNICAS DE PROCESSAMENTO E/OU RECONSTRUÇÃO DE IMAGENS EM MRI - **AMANDA**
- INOVAÇÕES EM TECNICAS DE PROCESSAMENTO E/OU RECONSTRUÇÃO DE IMAGENS EM US
- INOVAÇÕES EM TECNICAS DE PROCESSAMENTO E/OU RECONSTRUÇÃO RADIOLOGIA INTERVENCIONISTA – **PAULO ZAGO**
- NOVAS MÉTRICAS DE QUALIDADE DE IMAGENS - **ELSA**
- INOVAÇÕES EM MATERIAIS E OBJETOS SIMULADORE PARA AVALIAÇÃO DA QUALIDADE DE IMAGENS - **RAPHAEL**

TERÇA 27/09

Isadora → Radiologia convencional

Krizia → Mamografia e tomossintese

Paulo Zago/Amanda/Jullianna → CT

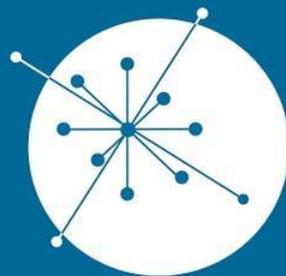
QUINTA – 29/09

Paulo Zago → Fluoroscopia e rad.intervencionista

Amanda → Densitometria

Carlos → Medicina nuclear

Jullianna → US e RMI



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