Image quality in multimedia applications

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Some “semantic free” image quality definitions

- Image quality is the integrated set of perceptions of the overall degree of excellence of an image (Engeldrum, 2000).
- Image quality is understood as the subjective impression of how well image content is rendered or reproduced (Yendrikhovskij, 2002).
- The quality of an image is defined to be an impression of its merit or excellence, as perceived by an observer neither associated with the act of photography, nor closely involved with the subject matter depicted (Keelan, 2002).

Image quality definitions

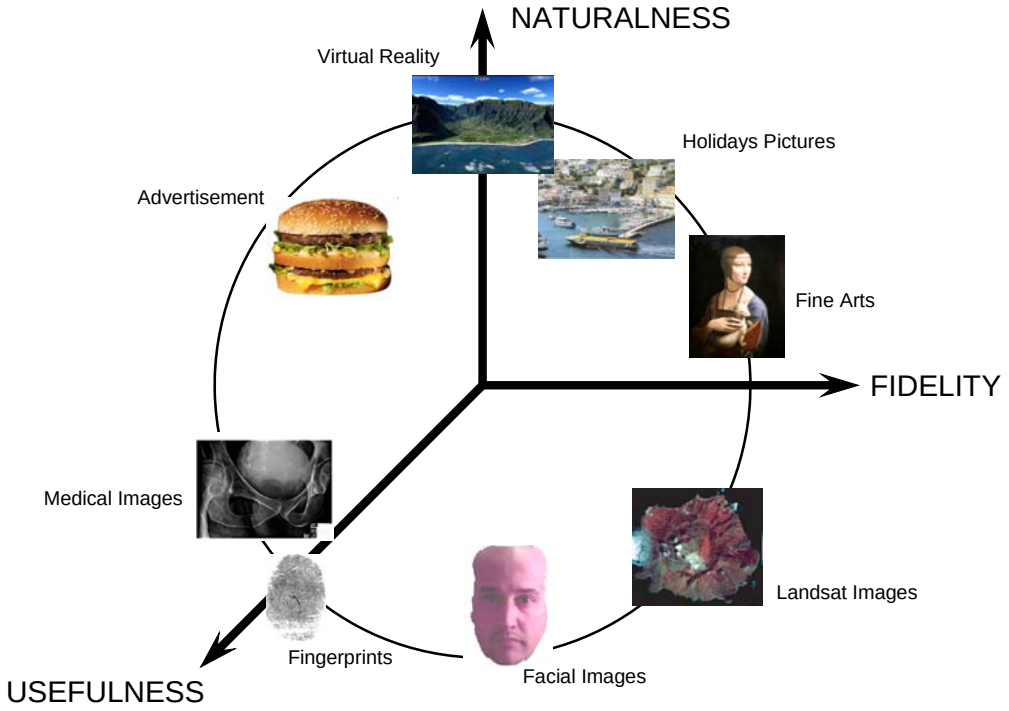
- According to the International Imaging Industry Association [2007], image quality is The perceptually weighted combination of significant attributes (contrast, graininess,…) of an image when considered in its marketplace or application.

photo: P. Burns

Image quality definitions

- The quality of an image is its degree of adequacy to its function/goal within a specific application field.
  - This definition does not see image quality *per se*, but considers that a lack of coincidence may exist between the acquired and the desired scenes.
  - This definition does not assume that the image receiver is a human but it could be a computational system moreover it makes more evident the relationship between the process of image generation and image quality assessment.

FUN: a Visual Quality Model



Yendrikhovskij, 1999

Fidelity is the degree of apparent match of the acquired/reproduced images with the original. *Genuineness or Faithfulness are sometimes used as synonymous.*
Usefulness is the degree of apparent suitability of the acquired/reproduced image with respect to a specific task.
Naturalness is the degree of apparent match of the acquired/reproduced images with viewer's internal references.

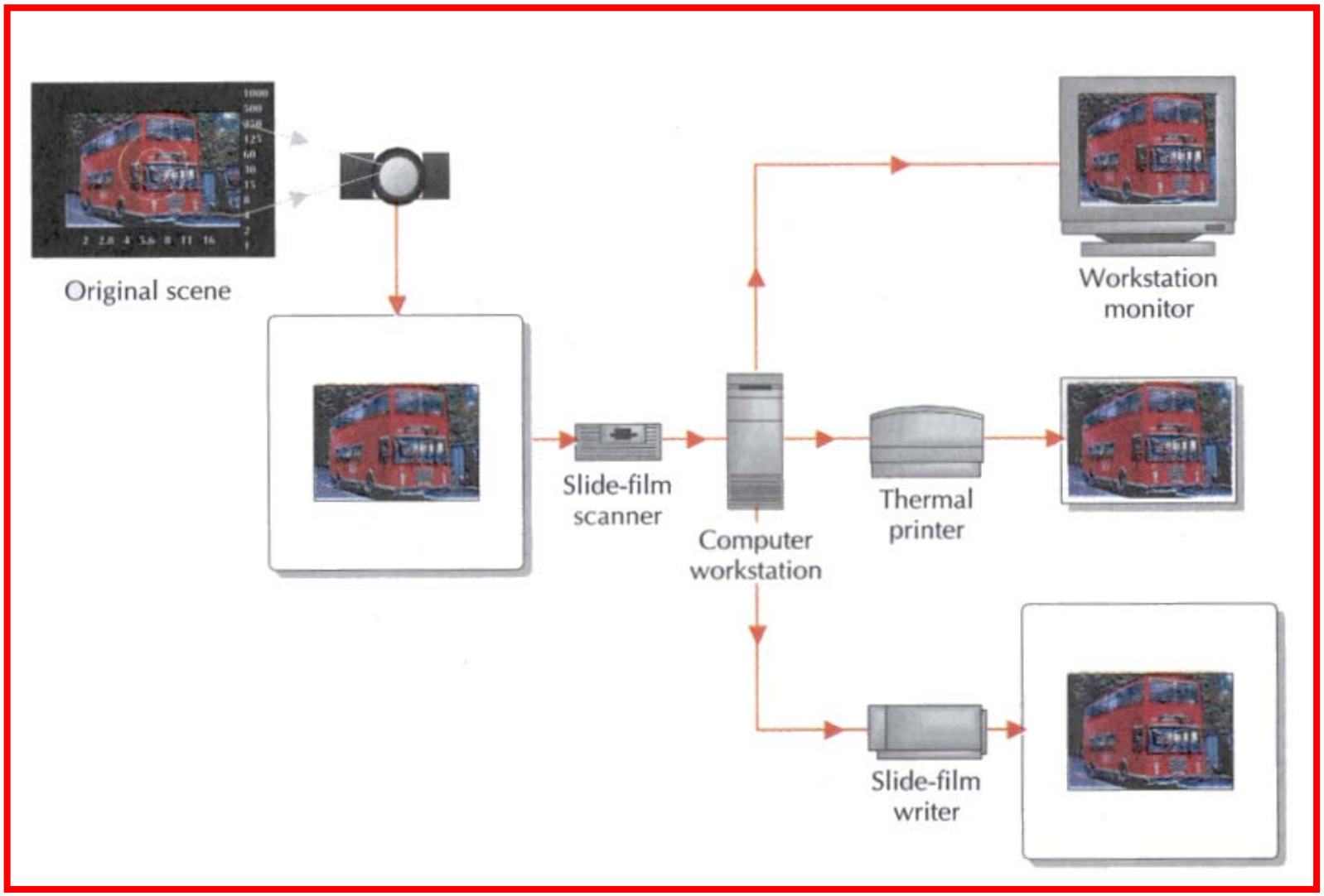
Perceived Visual Quality Vs. fidelity

Fidelity is the degree of apparent match of the acquired/reproduced images with the original.

Suppose that you want to create a catalogue of a famous (therefore very expansive) Italian stylist. Fidelity should be as high as possible.

The rendering of shape and texture can be difficult.
Color rendering can be extremely difficult.

Perceived Visual Quality Vs. fidelity



Perceived Visual Quality Vs. fidelity

Color fidelity is obviously related but it is not always predictive of image quality.

The first image is faithful to the original scene.
The second is less faithful but it may more attractive to an averaged observer.

Perceived Visual Quality Vs. Naturalness

Which image is synthesized ?

Perceived Visual Quality Vs. Naturalness

Naturalness is the degree of apparent match of the acquired/reproduced images with viewer's internal references.

These three images have different degree of **Naturalness.**

Suppose I have just changed the color of the t-shirt, ….

Perceived Visual Quality Vs. usefulness

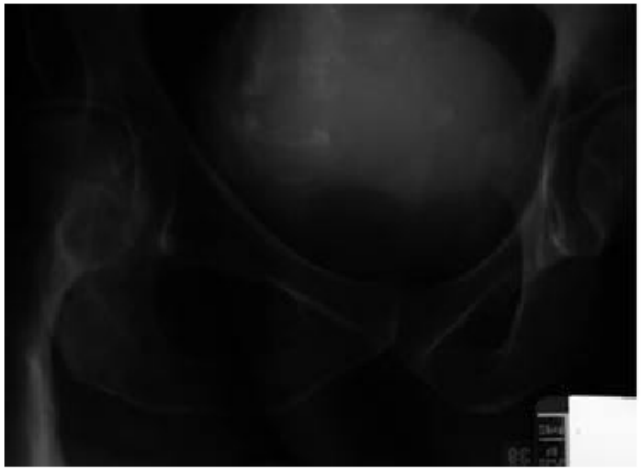
Usefulness is the degree of apparent suitability of the acquired/reproduced image with respect to a specific task.

Supposing that the task is people recognition, the two images have the same degree fidelity and naturalness, but different degree of usefulness for human and computer-based recognition

Perceived Visual Quality Vs. usefulness

Task: understand the rules of parking.
The image on the left has been captured during a foggy day, and it is has been processed using an image processing algorithm.
The second image may be more useful than the first one (averaged observer).
Background noise may go unnoticed, it is not irrelevant w.r.t. the task.

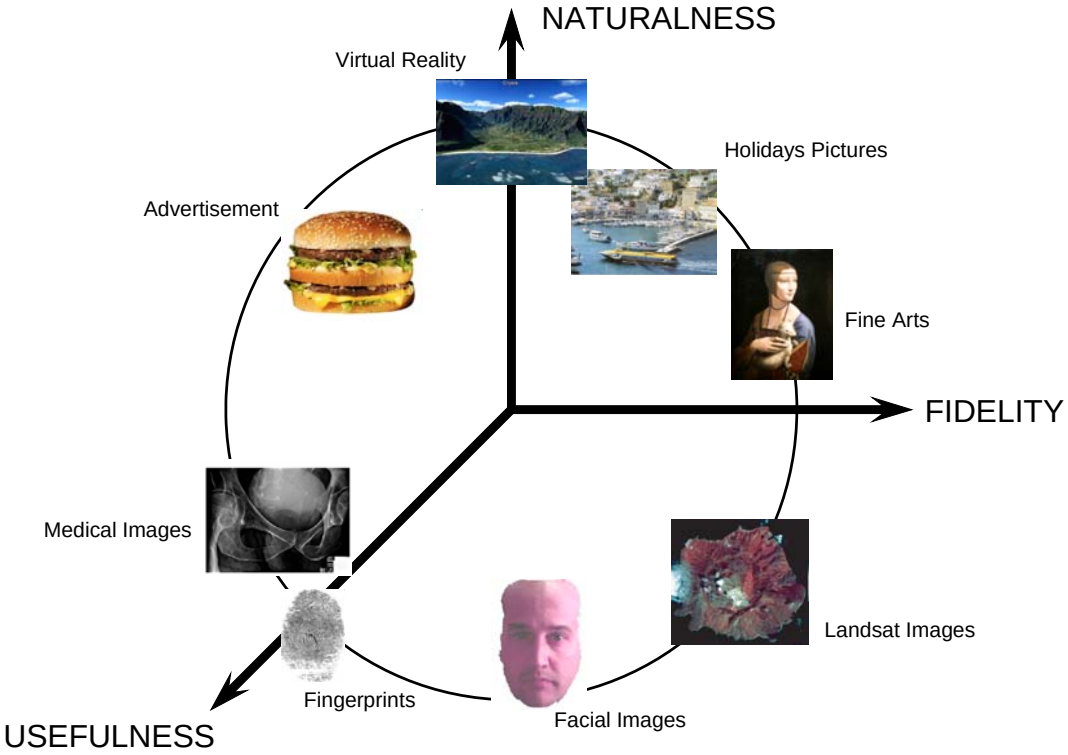
Perceived Visual Quality. quality dimension trade-off



Original

Retinex

FUN: a Visual Quality Model



MacDonald, 2002

The above introduced quality dimensions are not independent. The overall image quality may be considered as a weighted combination. The weights depend on the specific image data type, and on its function/goal within a specific application field.

Image quality source of information

If there is not an intrinsic image quality, what sources of information are exploited to evaluate it?

Four main sources:

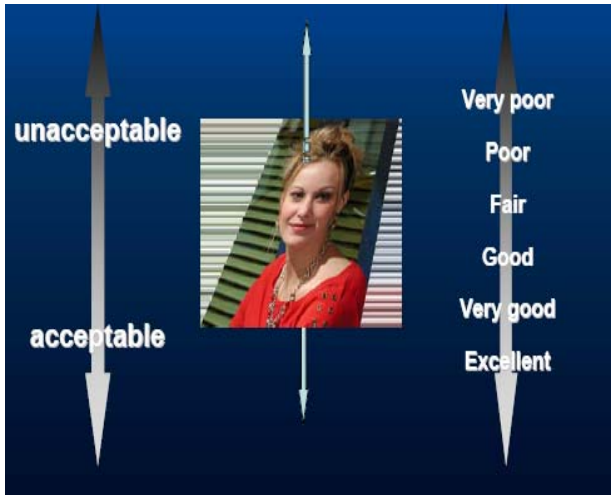
- Knowledge about image acquired (i.e. the original as a reference). Not always available.
- Knowledge about the imaging process, i.e. about the distortions introduced. Sometimes directly or indirectly available in the image metadata.
- Knowledge about the human vision system. Limited and very difficult to model.
- knowledge about how the image should look like. Application and observer dependant.

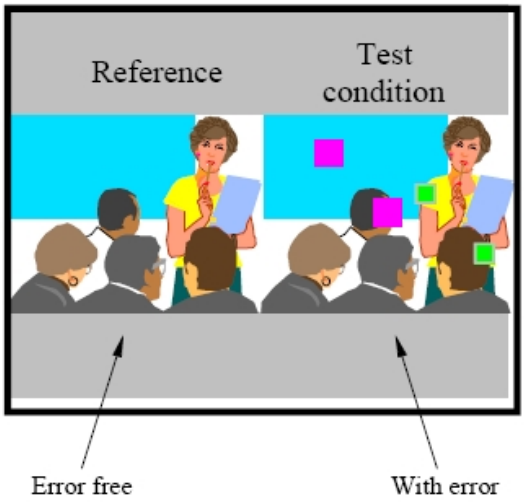
Image quality assessment

- Assessment is usually done by one or more of the following direct methods:
  - Psychophysical experiments involving human observers (subjective);
  - Computing suitable metrics directly from the digital image (objective).
- Image quality can be sometimes indirectly assessed by
  - Quantifying the performance of an image-based task done by the domain expert and/or by a computational system (objective).
  - Assessing the performance of the imaging/rendering devices on suitable set of target images using ad-hoc designed software tools one or more direct methods (objective/subjective).

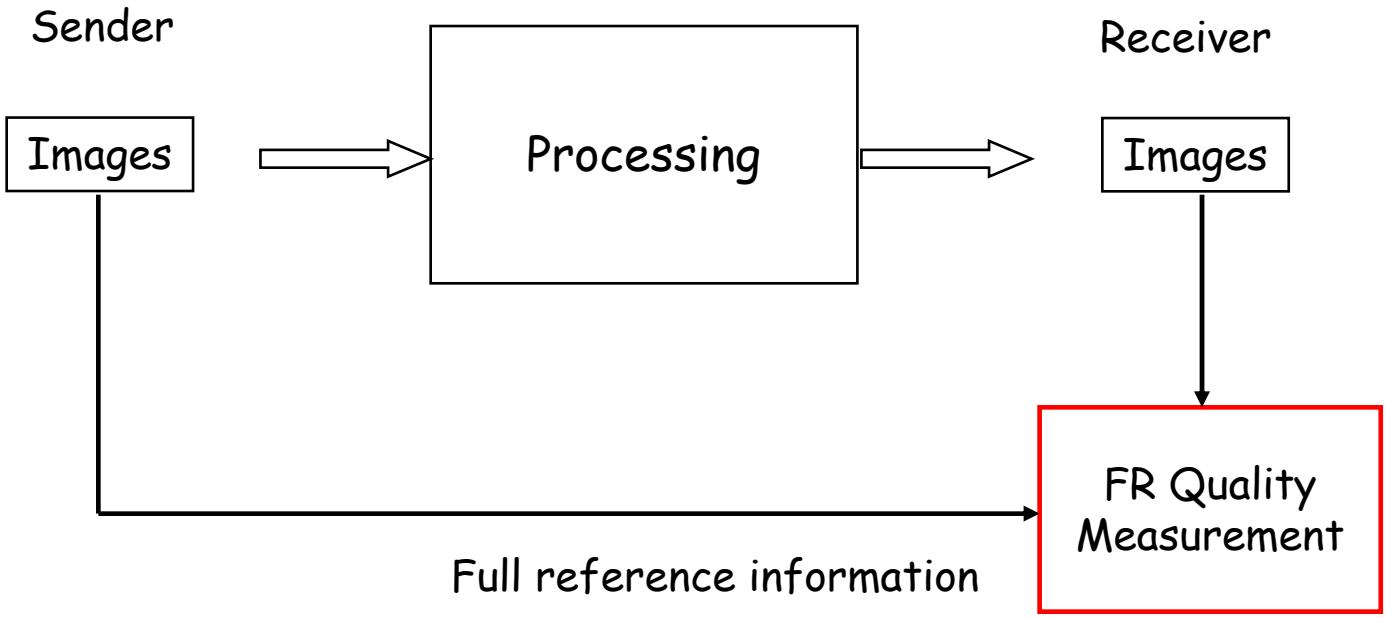
Subjective quality assessment

- Standardized procedures (ITU-R Rec. BT.500 (television), ITU-T Rec. P.910 (multimedia) for single and double stimuli (i.e. without a reference image, with a reference image).
- Subjective quality assessment is **very** expensive: many observers, careful setup, time consuming,..



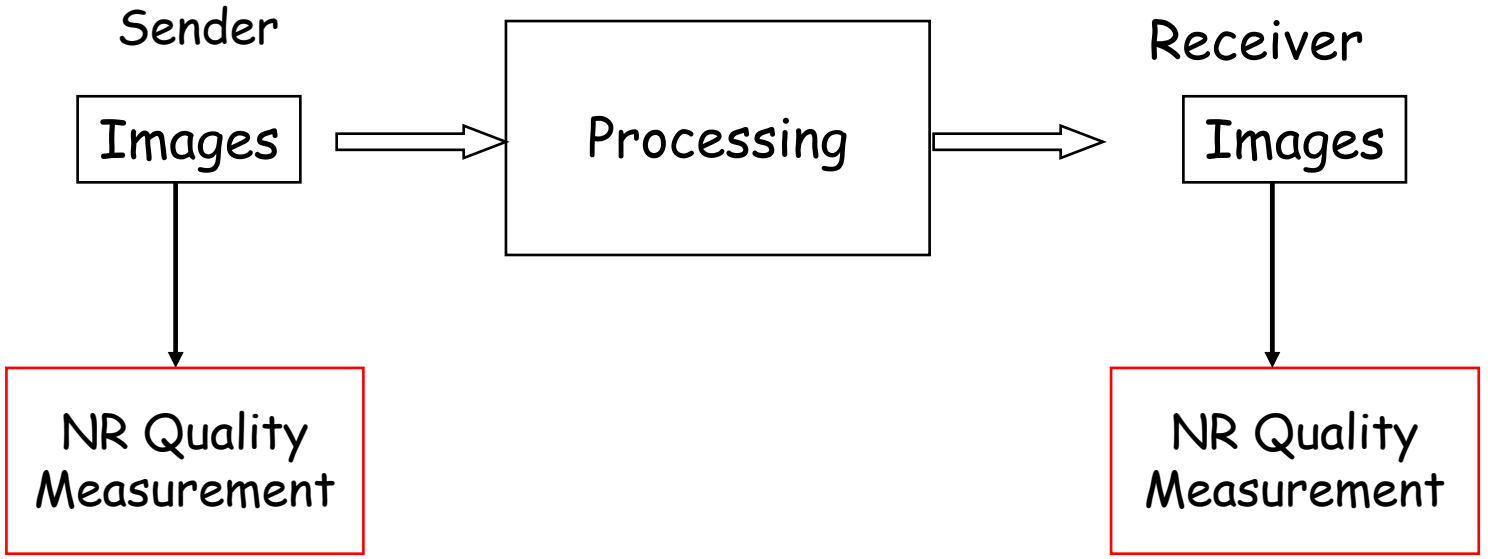


Reference image quality



Full-reference (FR) metrics perform a direct comparison between the image under test and a reference or “original” in a properly defined image space.
The requirement of the original is a restriction on the usability of such metrics. Just image fidelity can be assessed.

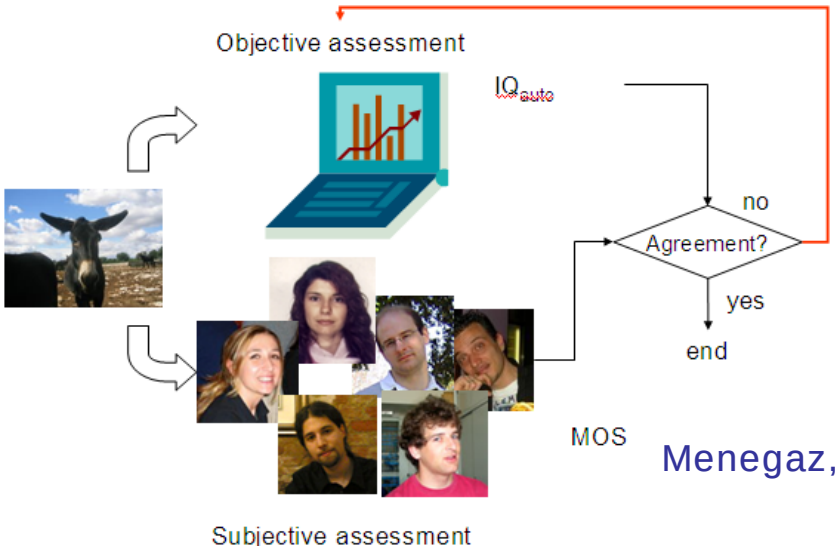
NO Reference image quality



We assume that image quality can be determined without a direct comparison between the original and processed image.
No-reference (NR) metrics look only at the image under test and have no need of reference information.
In theory it possible to measure the quality of any visual content (e.g. some attempts to quantify naturalness)
Information about the application requirements and users' preferences and/or task are required.

Subjective vs. objective image quality assessment

- Objective image quality aims to assess image quality automatically.
- Any automatic procedure just provide numerical measures that should be correlated to human subjectively (or to the application requirements) to be useful.



Menegaz, 2006

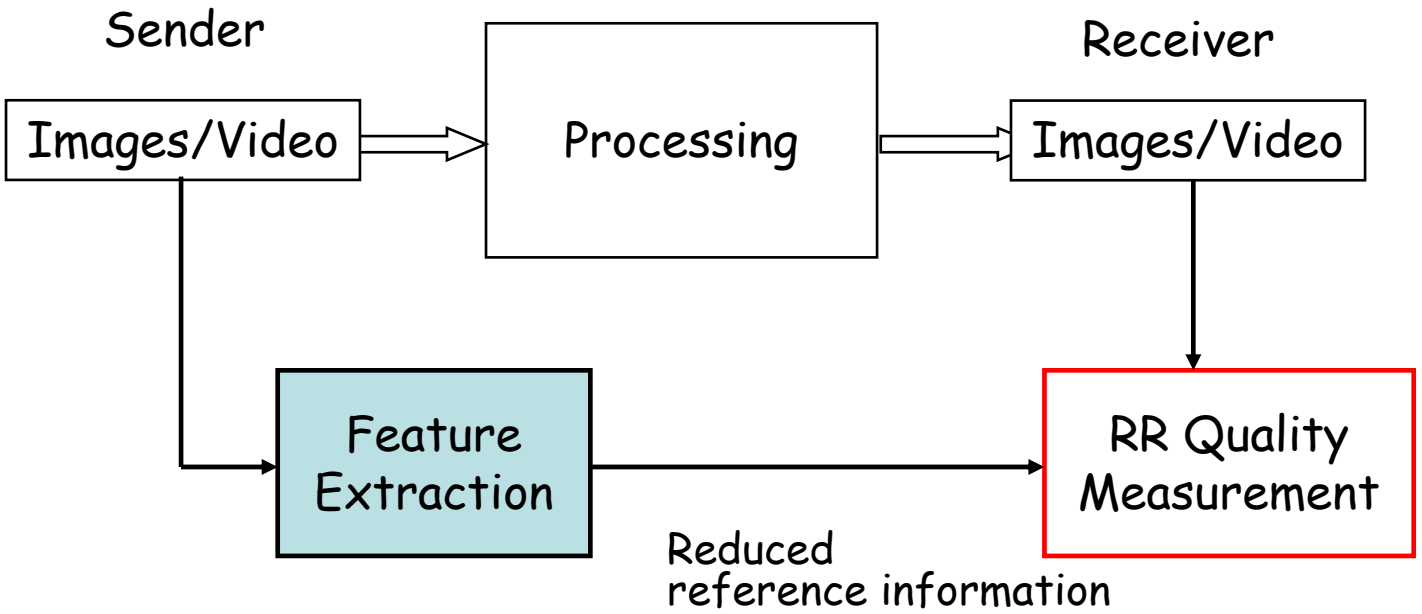
NO Reference image quality

distortions vs. regular image content

These three images exhibit some blurriness.

- How would you rate their quality ?
- Can you explain the differences, if any ?

Reduced Reference Metrics

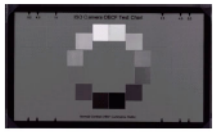


Reduced-reference (RR) metrics lie between these two No reference and Full Reference metrics.
They extract a number of features from the reference image. The comparison with the image under test is then based only on those features that are precisely characterized.
Just image fidelity can be assessed.

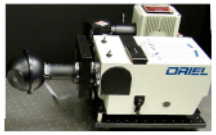
Task-dependent assessment

- Image quality can be indirectly assessed quantifying how the performance of an image-based task done by the domain expert and/or by a computational system.
- For example:
  - in the framework of medical imaging, an image is of good quality if the resulting diagnosis is correct.
  - In a biometrics system an image of a face is of good quality is the person can be reliable recognized.
  - In a OCR (Optical Character Recognition) system a scanned document is a good quality if all the words can be correctly interpreted.
  - ...
- Do not think just in terms of recognition rate. Different errors may be weighted differently.

Indirect assessment by device quality assessment

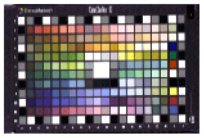


a.) ISO OECF target



b.) Monochromator Instrument

c.) Macbeth ColorChecker

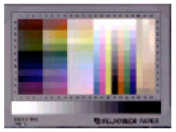


d.) Macbeth ColorChecker DC

e.) Esser Test Chart

f.) Cobalt blue target

g.) Gamblin oil paint target

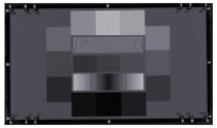


h.) IT8 target

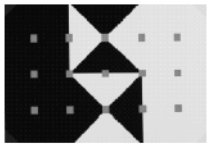
i.) Kodak Color Separation and Grayscale targets

j.) BCRA target

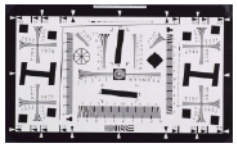
k.) D & H Color Rule



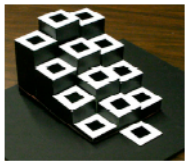
l.) ISO Noise target



m.) IEC spatial crosstalk target



n.) ISO Resolution target



o.) Depth-of-field target

For example, Berns et al. In the final report (2005) "Direct Digital Capture of Cultural Heritage – Benchmarking American Museum Practices and Defining Future Needs"
propose a set of TARGET-BASED ANALYSES for System Spatial Uniformity, Tone Reproduction, Color Reproduction Inaccuracy, Noise, Depth of Field and other more specific attributes. They uses general purpose and ad-hoc targets and made the tests following available measurements ISO and IEC standards.

Test targets used in the characterization of each museum's digital camera system and imaging workflow.

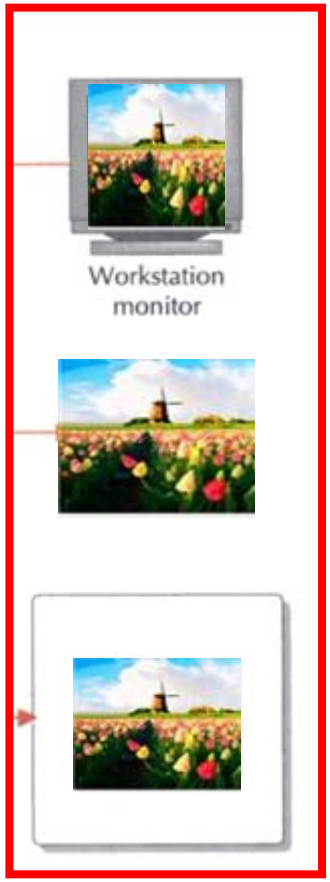
Indirect assessment by Device quality assessment

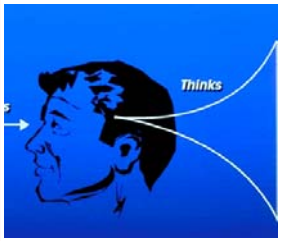
The Camera Phone Image Quality (CPIQ) Initiative of the International Imaging Industry Association (I3A) suggest both that objective and subjective characterizations.

1. Objective characterization should include estimations of Image Noise, Spatial Frequency Response, Exposure (proper motion blur/noise/clipping tradeoff), Color Balance (white balance) color Accuracy (scene analysis), Lightness & Contrast (tone reproduction part of color rendering), Colorfulness/Naturalness (color reproduction part of color rendering), Macro/Micro defects.

2. Subjective characterization should be carried out using standardized image quality assessment methods.

Image quality is a function of …



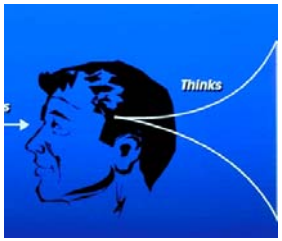


Type of scene;
Scene geometry;
Lighting conditions;
Specific content.

Observer's adaptation state and viewing conditions
Observers' previous experiences, preferences and expectations, .. task

Imaging device (HW and SW)
Image Processing and transmission
Rendering device (HW and SW)

Image quality is a function of …



The viewing conditions have a significant influence on the appearance of an image or because they can amplify or diminish the visibility of artifacts. This is why all the standards for subjective quality assessment pay a particular attentions to this issue.

William Blake Archive

Image quality evaluation should be conducted in a controlled environment.

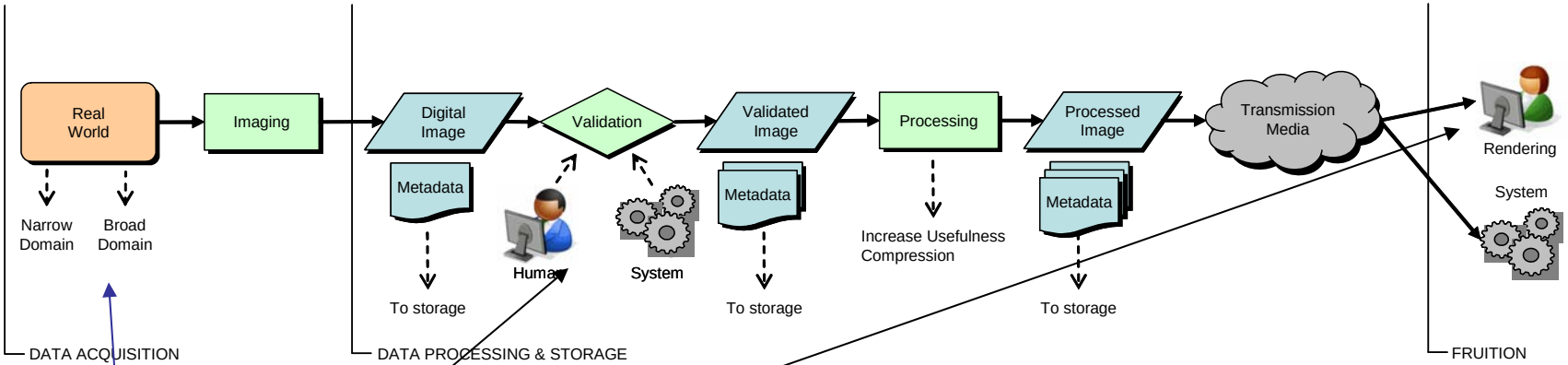
Example: Facial Image Quality

Standard requirements for digital passports

- The photograph must be in sharp focus and clear.
- The photograph must show your skin tones naturally.
- The photograph must have an appropriate brightness and contrast.
- The photograph must be color neutral.
- The photograph must show your eyes open and clearly visible (no hair across your eyes).
- The photograph must be taken with a plain light colored background.
- The photograph must be taken with uniform lighting and not show shadows or flash reflections on your face and no red eye effect.

We can note that some requirements refer to the scene (a plain light colored background,…), someone else to the lack of artifacts, others to naturalness,…

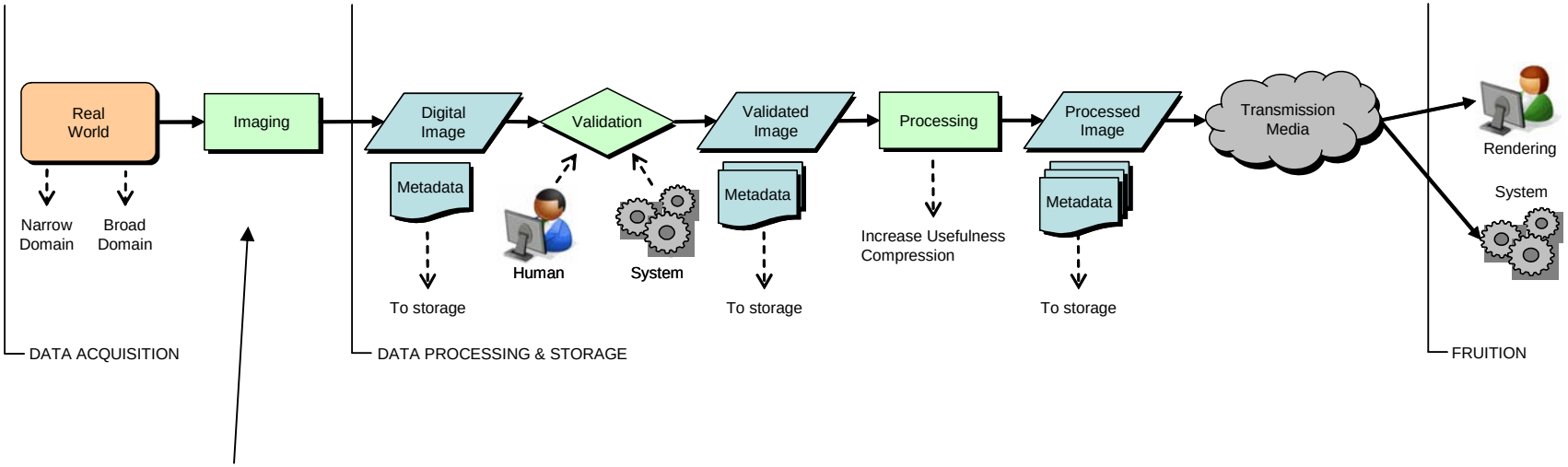
a generic image workflow chain



We may have a lack of coincidence between the acquired and the desired scene.

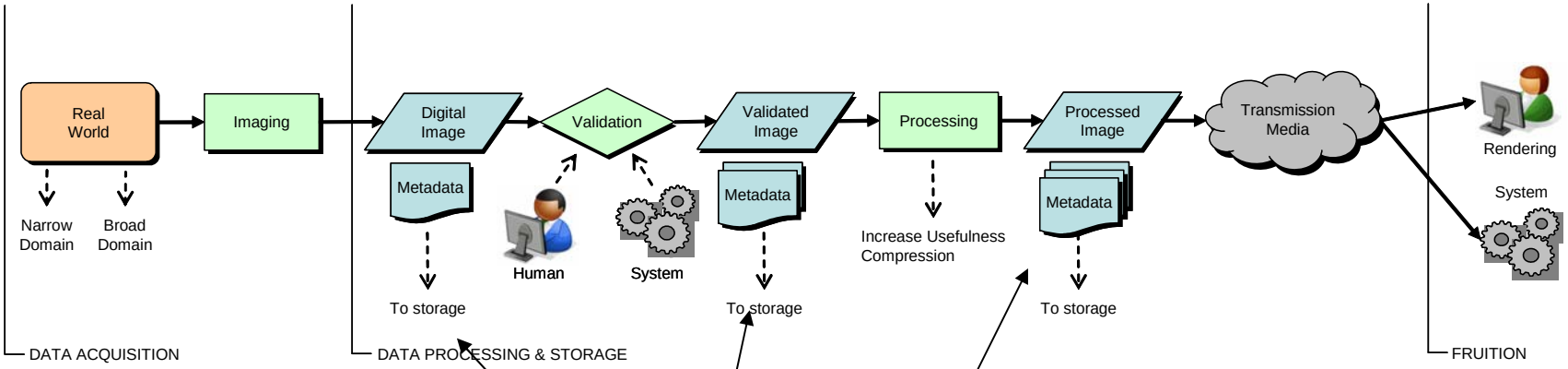
Image Completeness. “A digital image is complete is it depicts all the information it must convey”.

a generic image workflow chain



The characteristics of the imaging devices have an obvious impact on the quality of the acquired images.

Metadata



The metadata schema is usually set at the beginning of the digitalization stage and is based on application needs and the workflow requirements

Quality of image metadata

Unfortunately imaging device metadata may be wrong, modified or eliminated using software.

An example of wrong EXIF metadata

Proprietà	Valore
Width	800 pixels
Height	600 pixels
Horizontal Resolution	180 dpi
Vertical Resolution	180 dpi
Bit Depth	24
Frame Count	1
Equipment Make	Canon
Camera Model	Canon PowerShot S45
Color Representation	sRGB
Shutter Speed	1/403 sec.
Lens Aperture	F/4.9
Flash Mode	
Focal Length	21 mm
F-Number	F/4.9
Exposure Time	1/400 sec.
Metering Mode	Pattern
Exposure Compensation	0 step
Date Picture Taken	7/19/2003 11:31 PM

Date Picture Taken | 7/19/2003 11:31 PM

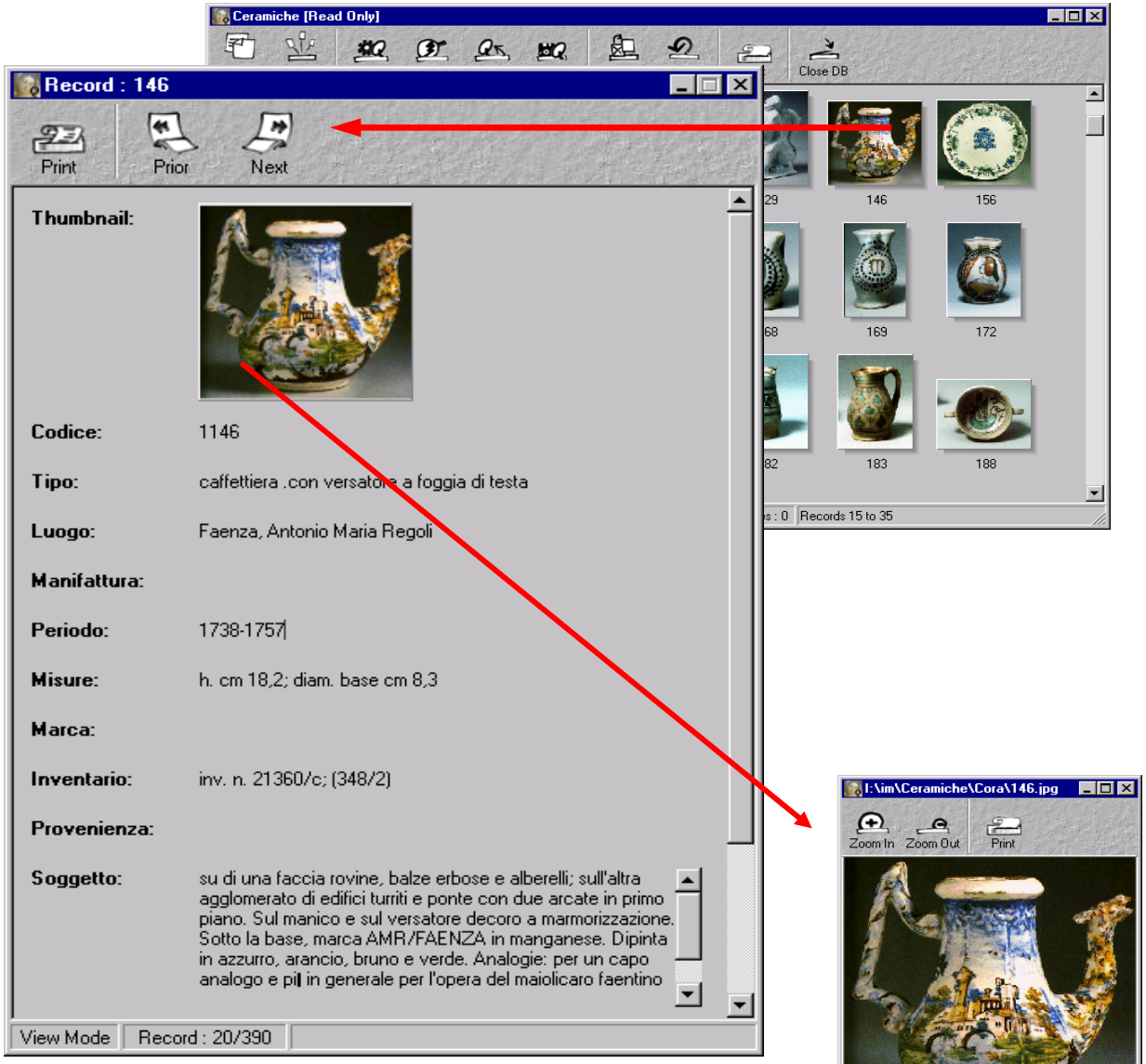


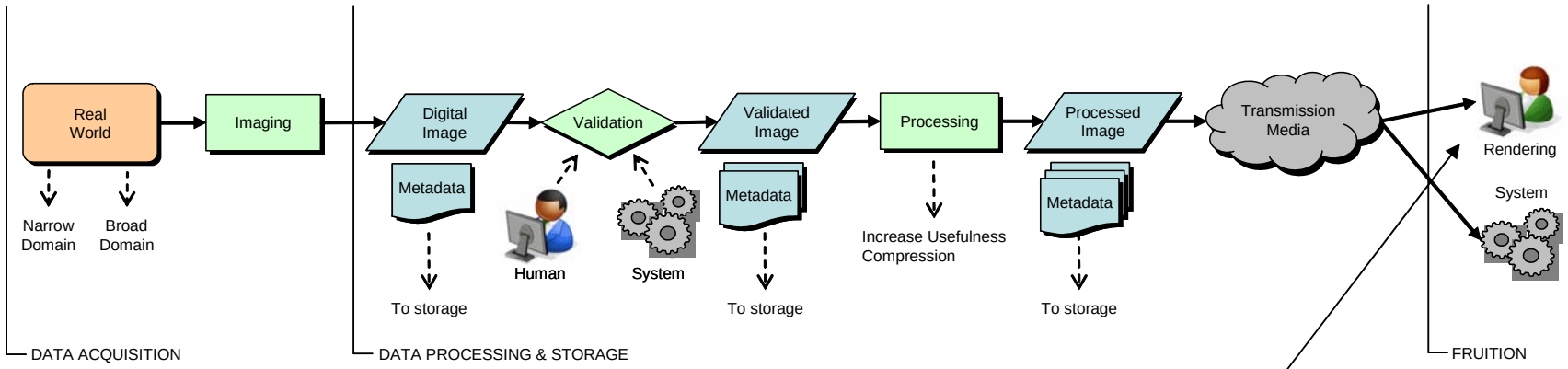
Image index

No unique standard.

Standard DB and text data quality procedures can be applied.

Content based image indexing?

Image quality assessment in the information systems life cycle



Rendering gap may be due to the HW/SW rendering devices, to the observers and to the viewing conditions.

Conclusions

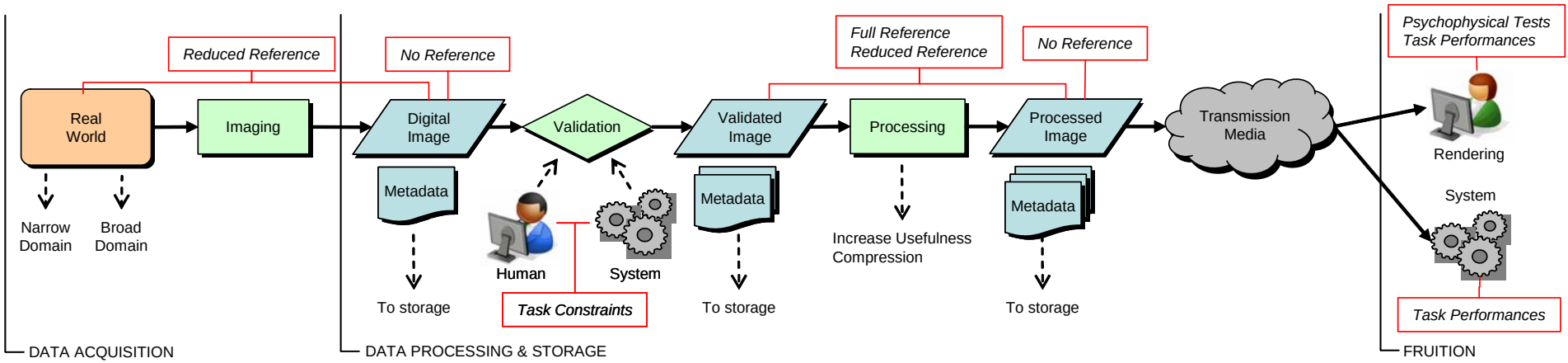


Image quality in multimedia applications is addressable by an integrated set of tools including:

-Image quality tools (full reference, no reference,…).

-Image analysis / pattern recognition tools.

-DB and textual image quality tools.

-**Open issues:** so many…

-ER 2008 Tutorial: Quality of Data, Textual Information and Images: a comparative survey, by C. Batini, F. Cabitza, G. Pasi, and R. Schettini.

Thank you!

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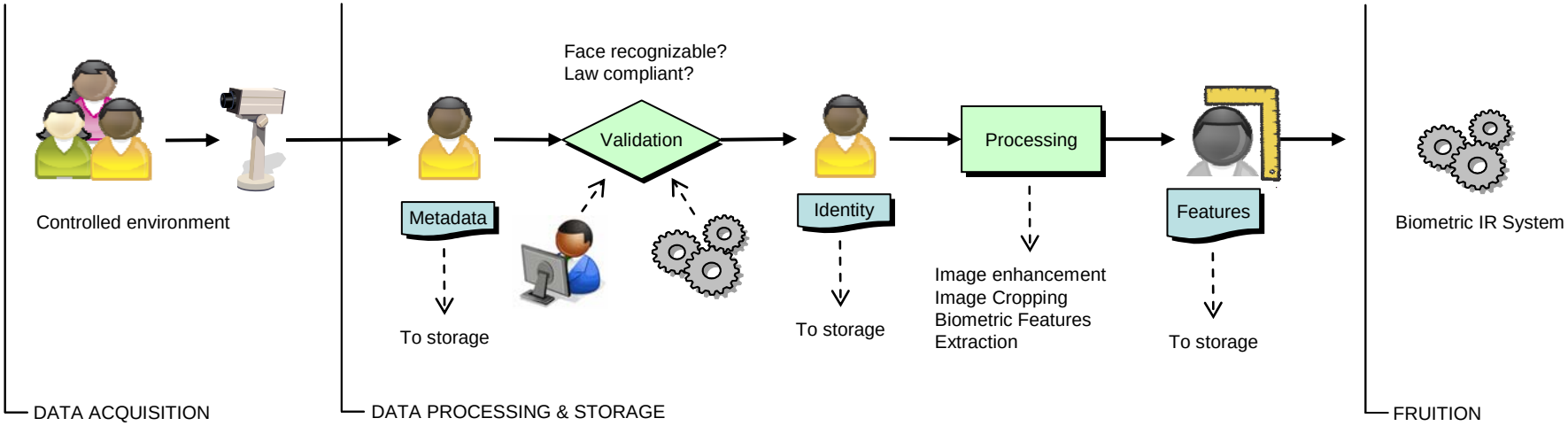
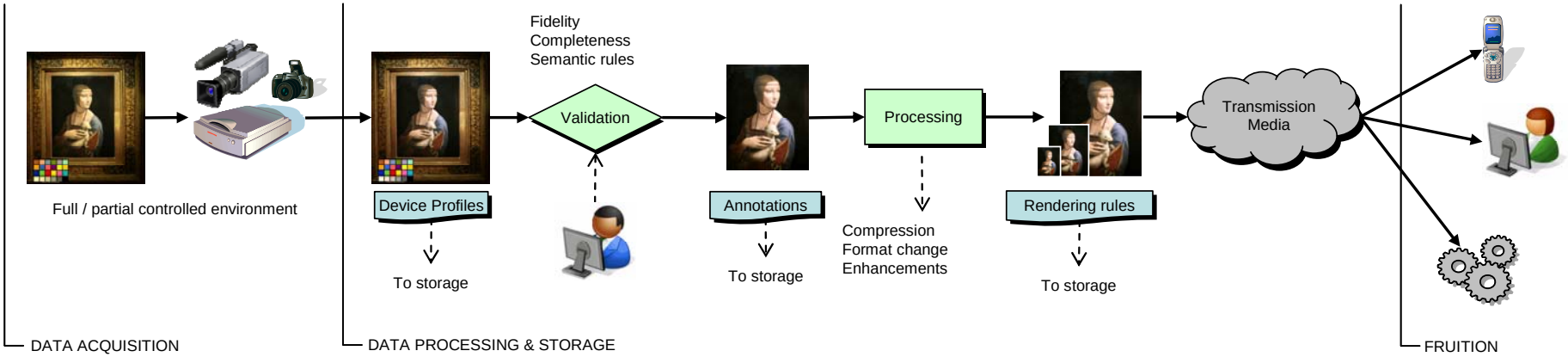
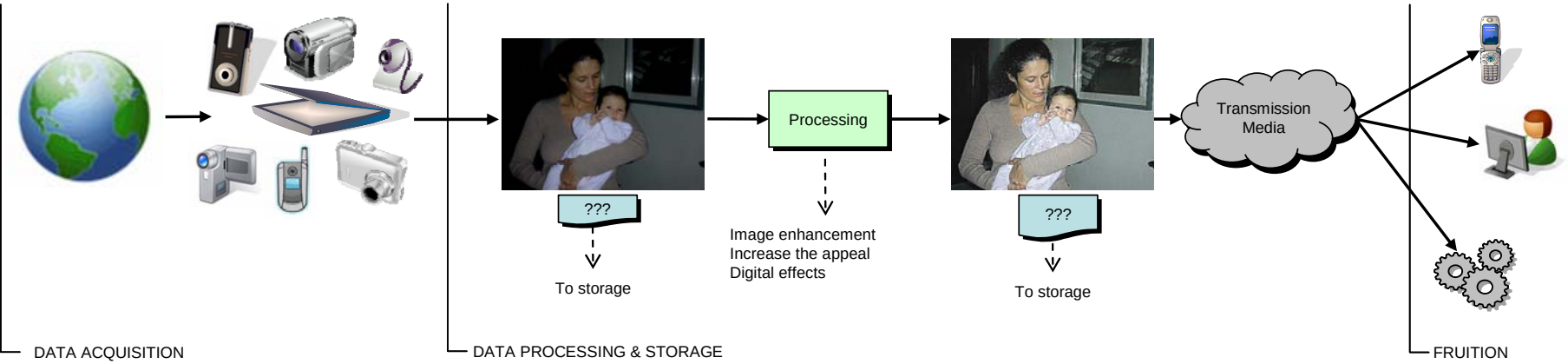

Face recognizable?
Law compliant?
Validation
Controlled environment
Metadata
To storage
Identity
To storage
Processing
Image enhancement
Image Cropping
Biometric Features
Extraction
Features
To storage
Biometric IR System
DATA ACQUISITION
DATA PROCESSING & STORAGE
FRUITION


Fidelity
Completeness
Semantic rules
Validation
Processing
Transmission
Media
Device Profiles
Annotations
Rendering rules
To storage
To storage
Compression
Format change
Enhancements
To storage
Full / partial controlled environment
DATA ACQUISITION
DATA PROCESSING & STORAGE
FRUITION


???
To storage
Processing
Image enhancement
Increase the appeal
Digital effects
???
To storage
Transmission
Media
DATA ACQUISITION
DATA PROCESSING & STORAGE
FRUITION