I-ImaS

CTI:

Concluding remarks and future prospects for improvements

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Overview of work undertaken:

1. Identification of important factors related to image quality (technical and clinical)

2. Definition of relevant image statistics (mainly texture), localized and global, that could quantify these image quality factors (e.g. content-rich tissue areas)

3. Experimental analysis and selection of the most prominent image textural/histogram features that correspond to changes in the local content of the image

4. Formulation of a robust and simple control model that uses these features as input to control the X-ray exposure parameters (mAs) optimally in terms of dose/quality

Overview of work completed:

1. Technical and clinical “quality” of X-ray images was defined formally for mammographic and dental images (RIEDS forms A-F: detailed documentation framework)

2. Image analysis was based on 1st-order statistics for increased speed and inherent parallelizable processing

3. Several textural features (20+ simple and composite) were tested and evaluated in several image DB sets against X-ray exposure, most prominent ones (5-7) were identified as “good” for automatic control input

4. Simple 1st-order linear feedback model was employed as the base for I-ImaS “content-aware” AERC-like control

Important issues completely resolved:

- TIME CONTRAINTS: Image data acquisition, pre-processing, feature calculation and feedback control should be completed within a very narrow timeframe for on-line run

- FAST RESPONSE: Rapid adjustment of X-ray exposure was successfully focused only on mAs, using the “indirect” procedure of wedge filters in front of the beam

- CONTENT-AWARE: A small set of simple yet effective image features related to texture/histogram was successfully linked to dose/quality improvements

- INTELLIGENCE: Control model is simple but effective

Important issues partially resolved:

- TIME CONTRAINTS: Due to these limitations, the complete I-ImaS cycle was intentionally "limited" down to very elementary image analysis or link to clinical attributes

- CONTENT-AWARE: Textural features of 2nd or higher order could provide tissue-discrimination information, i.e., provide the basis for a CAD-oriented feedback

- INTELLIGENCE: Control model is "forgetful" between the step-and-shoot cycles, i.e., it does not "follow" the tissue during the scanning process (⇒ sub-optimal performance)

- INTELLIGENCE: Currently, the I-ImaS control is focused primarily on "quality" (close-loop) rather than "dose" (open-loop), i.e., not both *at the same time*

Design of the desired system response:

Summary of I-ImaS Models for On-Line Control	**Reactive Control** (error-based)	**Reactive Control** (error-based)	**Reactive Control** (error-based)	**Anticipatory Control** (predictive)
	Simplistic "blind" optimization stationary	**Fully-Adaptive** "blind" optimization non-stationary	**Model-Matching** Use experts' "reference" points	**Model-Matching** Use experts' "reference" points
Direct Single-step analytical solution	**FG/BG Percentile +StDev Models** (SINTEF/UoT) tested/verified	**Weighted Linear Cost Model** (CTI) adaptive limits and quality/dose tpl.	**Weighted Linear Model** gain-directed *(see: report D.9)*	**Weighted Linear Model** gain-directed *(see: Trieste/06)*
Iterative Multi-step analytical solution	*Small-step adjustments (?)*	*Gradient-based algorithms (?)*	*Gain-directed gradient-based algorithms (?)*	*Gain-directed gradient-based algorithms (?)*
Heuristic Behavioral model (on-line learning)	---	---	**Reinforcement Learning Model** error-based *(see: Trieste/06)*	**Reinforcement Learning Model** predictive *(see: Trieste/06)*

selected design framework for I-ImaS ver.1 launch

Future prospects for I-ImaS ver.2:

- More IC speed within the on-line cycle means more time available for image processing and I-ImaS control
- Better pre-processing ⇒ better image as input, i.e., more noise-resilient and contrast-enhanced data to work with
- More complex features ⇒ more localized, more efficient, CAD-oriented, linked to clinical attributes (pathology)
- Embedded experts' models ⇒ use prior knowledge on clinical assessment of acquired images to improve the accuracy and clinical value of the resulting images

Future prospects for I-ImaS ver.2: *(cont.)*

- A combined weighted quality/dose "cost" model could provide the means for a fully adjustable I-ImaS system, i.e., for dose- or quality-oriented applications
- A fully-adaptive, multi-step I-ImaS system could be used for highly volatile and continuous-time imaging apps.
- With more on-line time/resources, more "intelligence" can be embedded into the control model (predictive control)

Conclusion:

- Current I-ImaS state proves the feasibility of the solution and it can be easily improved and extended in scope

Related References:

[23] *I-ImaS, Workpackage 3 – Deliverable D.8*, "Translating information signatures to a sequence of well-defined processing functions", Feb.2005

[25] *I-ImaS, Workpackage 3 – Deliverable D.9*, "Different approaches to providing intelligence to the sensor/imaging system", Mar.2005

[26] *I-ImaS, Workpackage 3*, "Update on current progress and deliverable report D.8", CTI presentation for 4th I-ImaS meeting, Oslo, 14-15 Feb 2005

[29] *I-ImaS, CTI*, "Top-level system designs", Mar.2005

[34] *I-ImaS*, "Enhancements to the image pre-filtering and image restoration options, and preface to x-ray camera geometry", CTI presentation for 5th I-ImaS meeting, Athens, 29-30 Sept 2005.

[35] *I-ImaS*, "Improved Adaptive Control by Anticipatory and Reinforcement-Learning options for the I-ImaS Controller Logic", CTI presentation for 6th I-ImaS meeting, Trieste, 10-11 Jan 2006.

[36] *I-ImaS*, "Summary of patent-related issues regarding Image Analysis and Controller Logic", CTI presentation for 7th I-ImaS meeting, Ioannina, 23-24 May 2006.

[37] *I-ImaS,* "Update on remaining issues regarding Image Analysis and Control Logic", CTI presentation for 8th I-ImaS meeting, London, 22-23 Nov 2006.