I-ImaS

CTI:

Summary of patent-related issues regarding Image Analysis and Controller Logic

Ioannina, 23rd – 24th May 2006

Work on Image Analysis and On-Line Control:

1. List of “good” texture extractors using 1st-order image statistics *(report D.8, Amsterdam/04, London/04, Oslo/05)*
2. Input Pre-processing Options: Gamma Correction *(Oslo/05)*
3. General Options for On-Line Control: “Simplistic”, “Fully-Adaptive”, “Model-Matching” *(report D.9, Oslo/05)*
4. Image Distortion/Restoration Models *(Athens/05)*
5. Overview of On-Line Processing “Pipeline” Assembly of Modules, Calibration Templates and Procedures *(Athens/05)*
6. Advanced Machine Learning Models for Customizable On-Line Control, Operational Profiles, “Reactive” and “Anticipatory” Implementations *(Trieste/06)*

Question:

Which of the above are desirable and suitable as claims within the context of a “universal” patent for the complete I-ImaS system?

Identification of suitable texture extractors:

Best feature functions (final):

- F01: “MIN”
- F02: “MAX”
- F03: “MEAN”
- F07: “POWER”
- F11: “VOLUME”
- SF19: (normalized power)
- SF20: (normalized exposure)

Additional candidate feature functions (with pre-processing):

- STDEV: $g < 1.00$
- SURFACE: $g < 1.00$
- SF17 (norm.surface): $g < 1.00$
- SF14 (mean.var): exp.decr. response

Current Status:

1. SINTEF has already conducted simulations for a simple control model, using a single (combined) input feature that implements a version of F01 and F02.
2. Results have shown that such an adaptive control can indeed produce the desired effects for the I-ImaS claims of on-line exposure control.
3. True performance depends on the sophistication of the final implementation in terms of: (a) number of textural features, (b) control model sophistication

(See: report D.8, Amsterdam/04, London/04, Oslo/05)

Summary of Adaptive Controller Profiles:

- Optimal Operational Profile (OOP): Use different modes of operation, namely for areas were tissue is or is not detected via specific textural features (e.g. SD).

- Optimal Response Profile (ORP): Use specific quality templates, asserted by human experts, for quantifying the notion of desired/optimal response by the controller.

- Optimal Control Profile (OCP): Implement a flexible adaptation model that exploits the current scout scan and internal logic/memory, in order to produce a good estimation of the best way to optimize the current image quality/dose index.

Current Status:

- OOP and OCP have been addressed in D.8 and D.9 reports. ORP requires experts' evaluation sheets on new images acquired from I-ImaS sensors.

(See: report D.9, Oslo/05)

Design of the desired system response (OCP):

- **“Simplistic”** : Easy to implement, provided a straight-forward “behavioral” design is evident for mapping feature vectors (states) into regions of optimal or near-optimal image quality (output). Feedback is calculated by means of reverse-mapping between image quality index and input.

- **“Fully adaptive”** : Does NOT depend on any type of embedded “prior knowledge” from experts and adaptation is local (iterative). However, it needs a minimum of 2-3 consecutive measurements at different states.

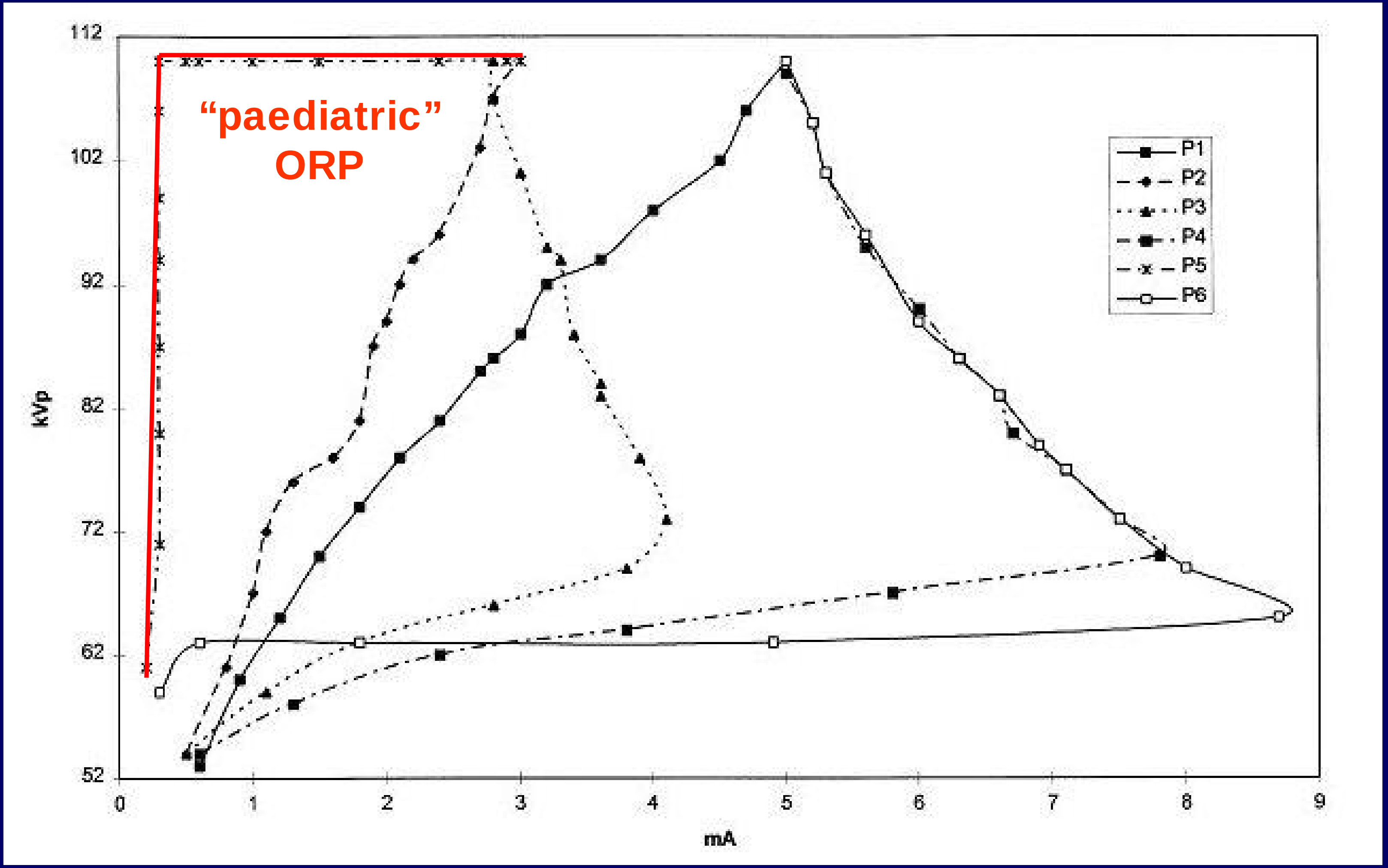
- **“Model matching”** : Prior “template” map is used as guideline for the image quality index space embodying the experts’ knowledge (response). Feedback is calculated directly for either local or global optimization.

Note: Details are included in the D.9 report (Mar.2005)

Current Status:

- “Simplistic” option has been tested successfully, but dose considerations require an extension into the “Model-Matching” option (combined quality index).

Example of ORP: Standard AERC curves (fluoroscopic)



Standard kVp/mAs exposure profiles (AERC) for a modern fluoroscopic unit [11].
P1: std 5 mA, P2: std 3 mA, P3: 4 mA high contrast, P4: 8 mA high contrast, P5: “paediatric”, P6: “iodine”

Overview of image distortion / restoration stages:

raw image acquisition

~~noise reduction~~

~~move/PSF correction~~

feature extraction

sensor-field correction

spot/pixel correction

gain/pixel correction

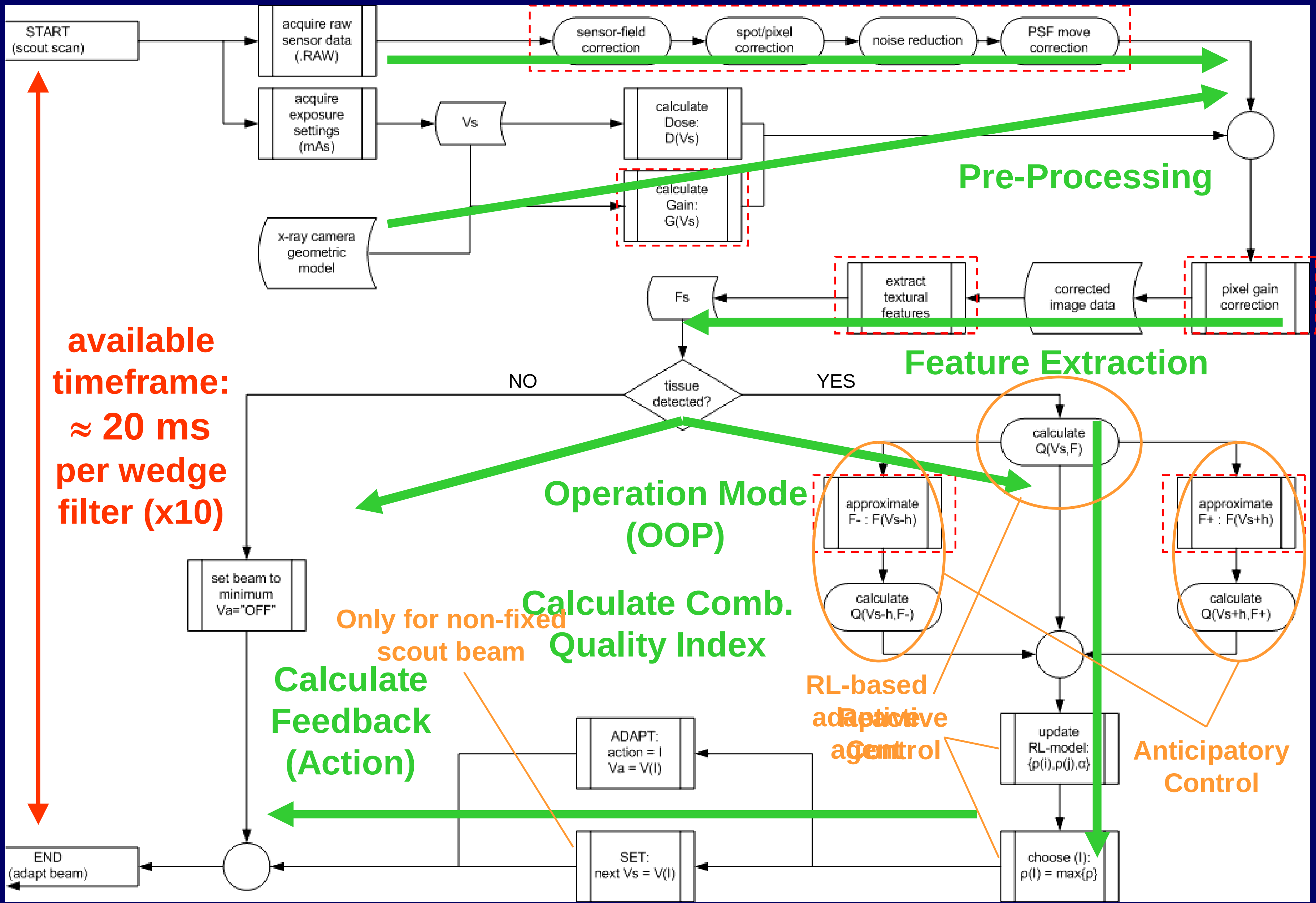
- Different stages embed different levels of complexity and processing time
- Exact ordering and sequence of the stages IS important for optimum results
- Ideal case: feature extraction comes after the last restoration stage
- Real case: embed as many stages as possible within the on-line loop

Current Status:

- Analytical models have already been studied, but intensive processing stages have to be dropped from the on-line loop.
- Test images from the I-ImaS sensors will determine the necessity of each of the individual restoration stages.

(See: report D.9, Oslo/05)

Overview of “innovative” work in WP3



Design of the desired system response:

Intelligence Level

Estimated Complexity

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" non-stationary	Model-Matching Use experts' "reference" points	Model-Matching Use experts' "reference" points
Direct Single-step analytical solution	**SINTEF model** tested/verified *(see: report D.?)* **1** / **1**	***SINTEF model***, *with dynamic limits and rules (?)* **2** / **1+**	**Weighted Linear Model** gain-directed *(see: report D.9)* **5** / **4**	**Weighted Linear Model** gain-directed *(see: Trieste/06)* **12** / **20**
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)* **13** / **9**	**Reinforcement Learning Model** predictive *(see: Trieste/06)* **30** / **27**

Remaining phases of work for I-ImaS “intelligence”:

Images from I-ImaS sensors

Dose Measurements

Statistical Analysis

Evaluation from Experts

Required Pre-Processing

Texture-to-Quality LInear Model

Combined Index (Quality+Dose)

Calibration Protocols

OOP

OCP

ORP

Final I-ImaS Image Analysis

Final I-ImaS Adaptive Control

Suggestive References:

[21] “I-ImaS, Workpackage 3, “Update on current progress and preliminary results for the on-chip processing”, presentation for 2nd I-ImaS meeting, Amsterdam, 26-27 May, 2004.

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

[24] *I-ImaS, Workpackage 3*, “Update on current progress and report for deliverable D.8”, CTI presentation for 3rd I-ImaS meeting, London, 12-13 Oct 2004

[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.