Image Analytical Sampling - Method, Prospects and Limitations

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Image Analytical Sampling (IAS)

Physical sampling of product – and process streams is well covered by the Theory of Sampling (TOS), pioneered by Pierre Gy since 1950. There are many situations in today's industrial practice, where it is desirable to rely on indirect sampling however (also called sampling-by-proxy). The reason behind this is real-time, on-line (at-line) quality inspection/quality assurance etc. Image Analytical Sampling is of the foremost examples of contemporary sampling-by-proxy. This technique is aimed at improving process and product quality control by use of digital images.

Image Analytical Sampling relies exclusively on a 2-D surface rendition of the product/process, as supported by a relevant image acquisition system (relevant for the task at hand). In this poster we refer to relevant, generic imaging systems without any details, while focusing on the most important specific Image Analytical Sampling issues:

- Presentation for the camera (e.g. conveyor belt)
- Illumination (type, number, angle)
- Camera (VIS, NIR, UV; 2-D; line-scan)
- Image preprocessing methods (FFT, Wavelet, AMT)
- Physical Reference Sampling (PRS)
- Traditional image processing
- Image analytical calibrations (e.g. Image PLS-regression, other)
- Specific material type issues (reflectance, absorption, resolution in comparison to e.g. particle size)

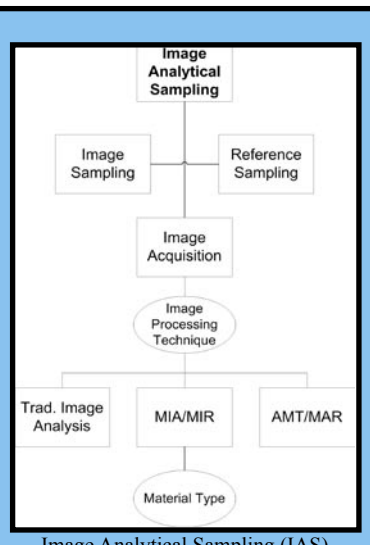


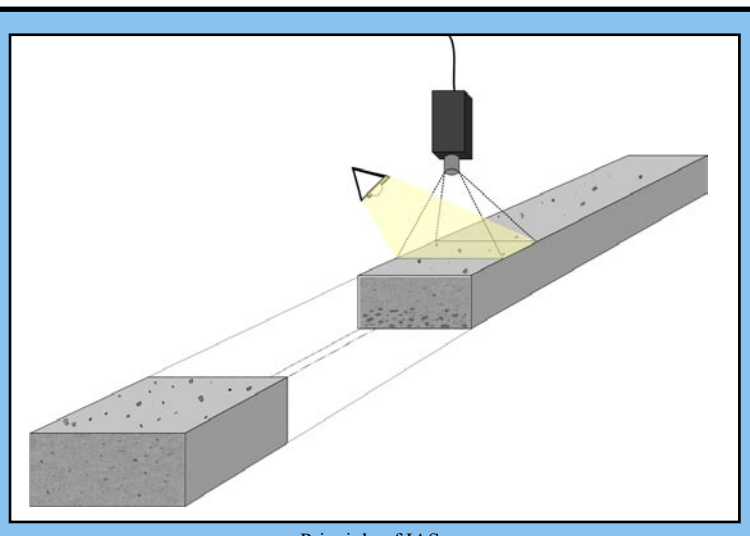
Image Analytical Sampling (IAS).

Materials – Sampling – Image Analytical Calibration

Physical Reference Sampling (PRS) provides the critical bridge to proxy-sampling (IAS) - see figure below.

PRS should make use of all relevant TOS facilities needed to provide a representative sample for analysis. Proxy-sampling by Image Analysis and PRS analytical results are related to each other by multivariate calibration.

ACABS' current work within IAS is focused on AMT/MAR (Angle Measure Technique/Multivariate AMT Regression) for surface texture and morphology characterization. Other applications deal with MIA/MIR (Multivariate Image Analysis/Multivariate Image Regression) or traditional image analysis.

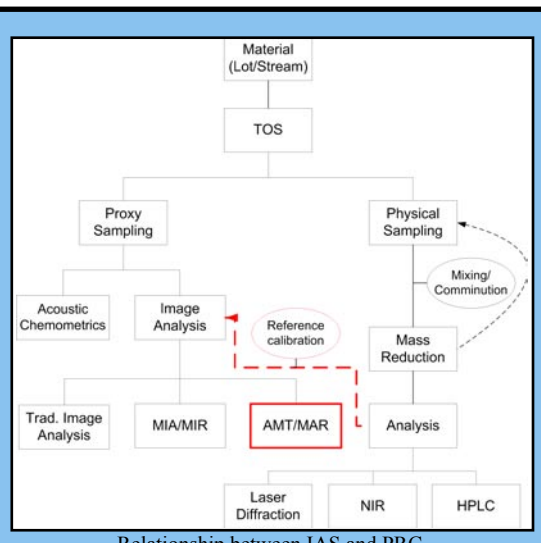

Principle of IAS.

Principles of Image Analytical Sampling – Critical Representativity

Materials which are not segregated in their natural state (high-viscosity bulks, slurries, solids) can be directly imaged – the IAS characterizations will be representative

Materials which are prone to gravity segregation need to be homogenized before presentation to the camera. This must take place immediately before image acquisition. Many mechanical homogenization engineering solutions can be conceived (not shown here)

The critical issue in IAS is related the degree of match, or mismatch, between IAS's 2-D rendition of the surface of a product – or process stream, relative to its bulk, 3-D characteristics. This forms the Critical Representativity Issue.

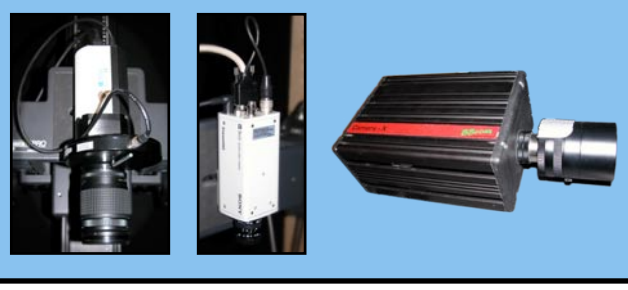


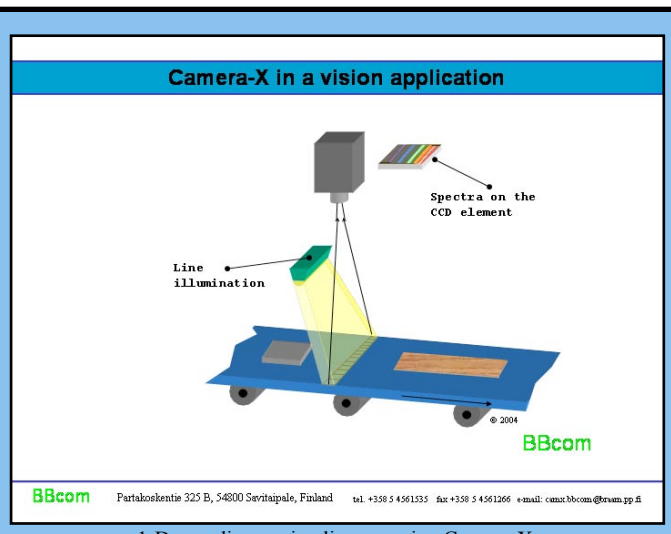
Relationship between IAS and PRC.

Image Analytical Sampling at Work

Camera-X is a joint product of BBCom & ACABS for line-scanning across 1-D product/process streams, f.ex. conveyor belts (illustrated right). Images can be acquired either as seamless 2-D arrays or as discrete 1-D multivariate images (320 pixels across - each pixel contains a 240-channel spectrum spanning 700-900 nm). The most used IAS acquisition mode consist of 1-D images obtained at regular intervals. This mode is completely analogous to PRS.

ACABS' current camera suite:

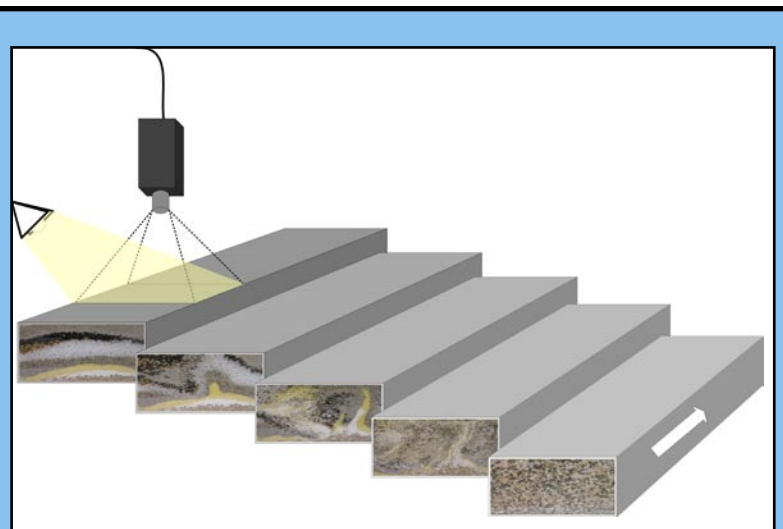




1-D sampling - using line-scanning Camera-X.

Importance of Illumination

Choosing optimal settings for illumination is of paramount importance to IAS. Both unilateral and bilateral illumination modes can be employed, as is omnidirectional light (below right). ACABS' current AMT studies mostly rely on unilateral, structured, low-angle illumination, but AMT can also be employed to other modalities, e.g. microscopic imagery, 1-D measurement series or technical data arrays (multi-dimensional data *arranged* in an image format: scientific visualization).



Critical Issue in Image Sampling: Representativity

To the left is illustrated five stages of a progressively more homogenized process stream, i.e. development of improved surface manifestations of the internal heterogeneity of a process stream. The critical representativity issue in IAS is centered around to which degree it is possible to guarantee complete homogenization of the conveyor belt lot just before image acquisition. The surface cross-section of physical reference samples, used in calibrating the camera, must be identical to the camera footprint.
If needed, development of an »on-belt homogenizer« is a challenging mechanical engineering task, which can be addressed individually from the optical system optimizations.

Sector	Examples of IAS Applications
Food & beverage	Process control in manufacturing of food (& feeds)
Polymer films	Process control of polymer films and coatings
Medical	Correlations between imagery and PRS (e.g. blood vs. NIR)
Powder industry	Aggregates, powders, mixtures
Paper & pulp	Quality control in lumber mills or process control in pulp and paper manufacturing
Commercial sheet & surface products	Classification of steel or aluminum surface quality. Control of surface appearance of consumer products, wood boards, paper texture (correlation with material characteristics)
Pharmaceutical	Raw materials inspection, mixtures, tablets, liquids etc.
Energy production	Fuels, wood pellets/chips, coal, oil, biofuel characterization

Examples of applications