WiggleCam

A method to cope with inter-sensor gaps for high-framerate tiled sensor arrays

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Introduction & background
Radiation Physics @ UGent

Lab-based X-ray micro-CT & XRF

Radiation Physics group supports user facility, improves micro-CT state-of-the-art
Radiation Physics @ UGent

“Next Big Thing”: Energy dispersive X-ray imaging at lab sources

But...

Monochromatic lab X-ray sources rare, expensive & large

Alternative approach:

Move energy selection to detector side
Energy dispersive detectors @ UGent

**SLcam (pnCCD)**
- 1.2 cm by 1.2 cm
- 450 µm Si
- 264 x 264 pixels
- Up to 30 keV
- 144 eV FWHM @ 6 keV

**HEXITEC**
- 2 cm by 2 cm
- 1 mm CdTe
- 80 x 80 pixels
- Up to 160 keV
- 800 eV FWHM @ 60 keV
Hyperspectral X-ray sensors

1. Sparse frames (< 10% occupancy)

2. Large number of sparse frames processed into one exposure

3. Frame rates as high as possible
The ideal hyperspectral sensor

1. Easy to integrate in existing systems
2. Stable, performant & efficient read-out
3. Full control over frame processing
4. Large (tiled) field of view
5. High frame rates (> 10 kHz) for “high” fluxes
6. Flatpanel-like FoV (10s of cm²)
7. Flux capability comparable to integrating detectors
The SpeXIDAQ framework

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Tiled arrays

Only realistic way to construct larger hyperspectral cameras

But...

Tricky artefacts for CT reconstruction

Typical solution:

Multiple exposures, stitched in post-processing

HEXITEC 2x2 imaging a Medipix 2
Our solution: WiggleCam

- Takes advantage of custom software and full control over every single frame
- Deeply integrates multiple exposure & stitching process
- Virtually no overhead for camera user

Getting perfect images is responsibility of camera & readout, not user!
WiggleCam requirements

- High framerate (multiple kHz)
- Long acquisition times (seconds or longer)
- Sensor mounted on XY-stage
- Position measurements better than half of a pixel size

Actual example

- HEXITEC 2x2 system
- 6.3 kHz framerate
- Integration times of well over 10 seconds
- 250 µm pixels
- XY-stage better than 100 µm
WiggleCam operating principle

1. Define a slightly larger **superframe**

2. Integrate each **physical frame** at correct offset in superframe

3. “Paint” entire superframe by following path that covers it completely

Multiple exposures & stitching @ 6.3 kHz
WiggleCam example images
WiggleCam example images
Non-uniform exposure

- **Oops**: uneven exposure time for different parts of superframe
- Store **exposure frame**: per-pixel counter of actual integrated number of frames in that superframe pixel
- Normalise final image to virtual gapless exposure
Bonus trick: super-resolution

Physical 250µm pixels
80 x 80

Virtual 125µm pixels
160 x 160

Virtual 62.5µm pixels
320 x 320
Bonus trick: super-resolution

Physical pixel pitch 250 µm

Virtual pixel pitch 125 µm

Virtual pixel pitch 62.5 µm
WiggleCam pros & cons

**PRO**
- Gapless images
- Spectral performance preserved
- No overhead
- Virtual pixel pitch < physical pixel pitch
- Faulty pixels masked

**CON**
- Moving parts add failure points
- Less compact
- Slightly more complicated noise profile
- Flux still limited by physical pixels
  ...or...
  Virtual pixels of half the physical pitch require 4x the measurement time for equivalent statistics
Further development
Implications for hardware implementation

- Position measurement critical
- Actuators don’t matter much
- Position reports directly to FPGA, embed in frames
- Minimise moving mass: integrate movement stage directly in camera
New HEXITEC readout hardware

Currently being developed:

1. HEXITEC readout with 2 x 3 sensors
2. Fully integrated WiggleCam parts

Poster 2D-08

A new six-sensor HEXITEC readout incorporating the WiggleCam technique
Thank you!

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