Specialised Image Capture Systems for a DIET
Breast Cancer Screening System

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• **Breast cancer** has second highest mortality rate of all cancers for women worldwide. In New Zealand it is number one.

• **Mammography** is the standard for breast cancer screening
  – discomfort to patients and health risk (exposure to radiation)
  – interpretation of images is subjective $\rightarrow$ misdiagnosis, false positives

• **Digital Image-based Elasto-Tomography (DIET)** is an emerging low cost technology for non-invasive breast cancer screening
  – digital imaging of actuated breast to determine tissue motion
  – 3D internal tissue stiffness reconstruction (finite element method)
  – Regions of high stiffness suggest cancer

• **Requires up to 100 Hz image capture** (5-10 cameras ideally)
  – **Problem:** Cameras too large and expensive (~ $15-20k US each, high resolution)
  – **Solution:** “Off the shelf” CMOS imaging sensors combined with Stroboscope
The DIET system is broken down into 4 fundamental steps:

1. Actuation → 2. Image Capture → 3. Motion Tracking and measurement → 4. Tissue stiffness reconstruction
Image capture

- Image capture for DIET system → 50-100 Hz

- This research implements stroboscope with Kodak’s KAC-9648 color imaging (resolution of 1280x1024)

- Other high speed cameras are either expensive, bulky or have reduced resolution

- CMOS Sensors allow dense array of cameras placed about the breast
Image capture apparatus and computer setup

- **stroboscope**
- **silicon phantom**
- **actuator**
- **two cameras**
Image capture - overview

- The frame rate of each CMOS camera at 1280x1024 is approximately 18fps
- To overcome this insufficient frame rate the breast is strobed at specific points in its motion

- In practice time between captured images 1-10 seconds ➔ 100-1000 cycles between images
Two configurations for cameras, implemented using I²C bus:

1. Initialization for camera → stream image data continuously to frame grabbers (to adjust colour gains, focus, camera position, aperture size)
2. Allows camera to trigger strobe itself

- First pin receives pulse and starts frame exposure
- Second pin supplies pulse to activate strobe
Actuator and Trigger Control

- dSpace™ control system drives image capture process (generates and synchronizes all signals)

**Process of strobe trigger**

- dSpace™ drives trigger signals and actuator using loaded Simulink™ diagram
- ControlDesk™ software allows real-time adjustment of settings on dSpace™ module
- Python™ is used to automate ControlDesk™
Image capture software – user interface

• Features of the Image Capture Application

• Can look at images and make real time adjustments (camera position, colour, …)
Preliminary results and problems

- Time period between receiving trigger from dSpace™ and camera triggering strobe is inconsistent and unpredictable
- dSpace™ triggering is consistent
- Camera is consistent at a frequency of 10Hz and not 100Hz

Signal sent from dSpace™

Camera takes picture (wrong point in cycle)
Correcting the timing

• The timing issues were solved by implementing an ‘AND’ gate and a feedback signal to dSpace™

• When left AND right cameras are ready for strobe, dSpace™ waits until the signal aligns with actuator, then it lets the strobe flash

Camera can wait up to 0.25-0.3 s before flashing (plenty of time to align with LVDT)

Flip signal, as strobe fires on falling edge by design
Results - timing

- Illustrates the accuracy in timing of the system
- Mean absolute error $\sim 1.4\% \rightarrow$ time difference of 0.0002 seconds
**Results – Actuator displacement vs ideal**

Actuator displacements (10 degrees of phase) plotted as a waveform (total time=~6 minutes)

Snap shot of actuators motion at t=1.82 s

Average of 20,000 waveforms (200 seconds)

- Results consistent → errors are physical limitations of current actuator (frequency varies from 95-100 Hz)
Experimental results

- Silicon phantom 50mm diameter, 40mm height
- Actuation frequency = 100Hz
- Amplitude = 1.2 mm

- Six images shown (60 degrees)
- 54 black dots
- 36 images = 10 degrees phase lag
3D motion tracking

point detection

surface reconstruction (snap shot during actuator cycle)

Virtual silicon phantom constructed by symmetry – agrees with visual images throughout actuation (further validation)

- Therefore captured images allowed successful tracking of the dots applied to the surface of the phantom
Further results

- ~750 coloured fiducial marks
- 100 red, 300 blue, 350 green
- Frequency=50Hz, 1mm peak to peak
- 20 images (18 degrees of phase)

- 90% of fiducial marks tracked successfully by point tracking method (see paper)
- Based on calibration accuracy, points are tracked within 1-2% of the magnitude of the silicon response (<0.1 mm)

Example of points tracked

(a) whole set  
(b) Subset (zoomed in)
Conclusions

• “Off the shelf” CMOS sensors + strobe = low cost DIET imaging system

• Image capture system successfully tested from 50-100 Hz
  – User-specified triggering times accurately realized within 1.4%
  – Captured images allowed accurate point and colour detection
  – Accurate surface motion tracking at a high image resolution of 1280x1024

• Total capture time = ~6 minutes
  – Refining of Ethernet protocols and custom design system might reduce to 20-90 seconds

• Some limitations found for current actuator (e.g. 95-100 Hz)
  (to date has not shown to effect DIET system)

• Future Work:
  – Replacement of the dSpace™ module with a self contained microcontroller
  – Implementation of an auto focus system for the camera
  – More cameras → Realistic Breast phantoms → Clinical trials
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Questions ???