Proof of Concept

Final Report March 2016

Principal Investigator:	Dr Sanja Dogramadzi
Co-Investigators:	Mr Benjamin Winstone
Title of Study:	**Using a Tactile Sensing Capsule for Treating FI**
Aims and Objectives: (max 400 words)	This project has proposed to use a recently developed bio-inspired tactile sensing capsule, see Figure 1, to characterise muscular rectum action associated with faecal incontinence in order to understand the severity of the condition. The tactile sensing capsule is inspired by the interaction between the skin's papillae features and mechanoreceptors in the finger's flesh, Figure 2. This papillae / mechanoreceptor interaction is replicated in the capsule as an image processing task whereby artificial papillae attached to a soft deformable skin move in three dimensions when subjected to external mechanical forces which is recorded with an internal camera. The direction and distance each papilla moves relates to the type and location of the mechanical force applied. We suggest that this concept is highly suitable for sensing rectum contractions. Patient's muscular rectum strength can be assessed in 360 degrees around the capsule.

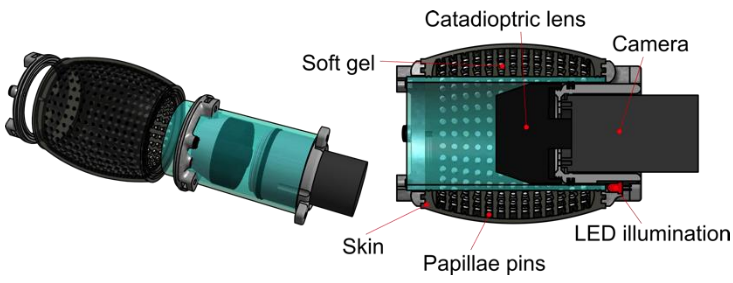

FIGURE 1 TACTILE SENSING CAPSULE

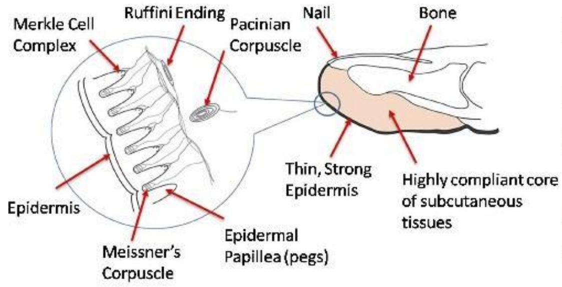

FIGURE 2 BIO-INSPIRATION

This vision based sensor uses a catadioptric mirror system to achieve the 360 degree vision field as shown in Figure 1. This image is then processed to measure the distance between the white dots or papillae. Previous experiments have shown the capsule capable of lumps detection through tracking movement of papillae, as presented by Winstone et al. 2015 [1].

FIGURE 1 INTERNAL VIEW OF SENSING CAPSULE

FIGURE 2 shows the test environment used for the lump detection experiment, whilst FIGURE 3 shows how the data captured create an accurate 3D visualisation of the environment. This approach lends itself to the proposed application of incontinence assessment.

FIGURE 2 LUMP DETECTION EXPERIMENT TEST RIG, WINSTONE ET AL. 2015 [1]

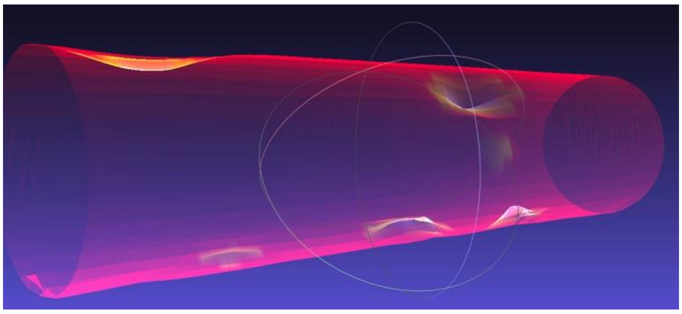

FIGURE 3 VISUALISATION OF DATA CAPTURED, WINSTONE ET AL. 2015 [1]

The main advantage of using such a device is improved repeatability and standardisation of the examination procedure, with potentially increased comfort, privacy and confidence for the patient. During this proof of study project we hoped to achieve the following aims;

<u>Aims:</u>

1. Establish suitability of the Sensing Capsule for recording rectum muscular contractions.
2. Develop algorithm to characterise different contraction strengths and contraction types
3. Present the sensed data in different formats

From these aims a number of clear objectives have formed;

<u>Objectives:</u>

1. Design and build a laboratory phantom to simulate rectum contractions
2. Characterise/measure rectum contractions using commercial pressure sensing devices
3. Compare measurements using tactile sensing capsule device
4. Develop software to distinguish between contraption types
5. Visualise real time interaction between the Sensing Capsule and the artificial rectum.

On starting the project and after discussions with the Leed's IMPRESS funding team it became apparent that a parallel project at Leeds university had proposed to develop a simulation rig complimentary to this proposal, so it was only logical to work collaboratively. This collaboration alters the objectives allocating tasks to the relevant parties.

Description of research work:
(max 400 words)

1 – Build a rectum laboratory phantom – (Leeds)

A test environment will be created to simulate the rectal function. A scaled simulation rig suitable to test the sensor will be built by the team at Leeds University.

2 – Establish the laboratory phantom characteristics – (Joint experiment)

A full range of contraction capabilities will be measured using commercial sensors to establish the ground truth. Leading up to a final integration experiment, Leeds will characterize their simulation rig.

3 – Test the Sensing Capsule on the phantom – (Joint experiment)

The contractions will be evaluated using the Sensing Capsule and comparing with the forces measured in task 2 to create a calibration algorithm. This will be achieved at a final integration day in the Leeds laboratory.

4 – Further improvement and testing of the sensing algorithm – (BRL)

After task 3 has identified the relationship between forces and the deformation of the sensing capsule, further testing is required to identify other sensor's characteristics such as identification of non-uniform contractions.

5 –Real time sensing data display – (BRL)

A software interface that shows real time information of the sensing capsule readings will be developed in collaboration with a specialist nurse.

<u>Software:</u>

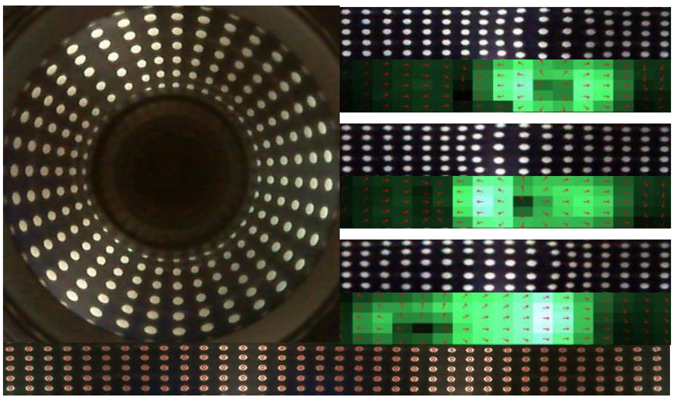

FIGURE 4 OUTPUT DATA FROM SOFTWARE

Software has been developed to capture images from the internal camera, unwrap (remove 360^{o} distortion), track pin positions and then determine the amount of surface deformation. Fig. 6 shows the output from the software, the raw image, unwrapped image with pins tracked, and regions of deformation above colour representation of movement.

<u>Experiment Setup:</u>

Fig. 7 presents the experiment setup. The Leeds simulation rig uses two silicone pneumatic actuators that sit around the sensor. When actuated they contract circumferentially around the sensor to recreate colon contractions. A number of configurations were attempted where frequency of contractions, phase offset, strength and obstructed contractions were explored.

Using the real time software it was easily noticeable that the actuator action can be detected.

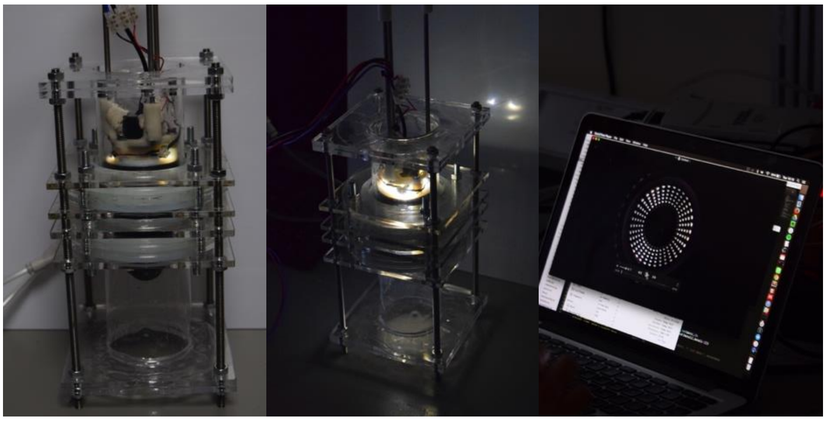

FIGURE 5 TACTIP CAPSULE INSIDE LEEDS SIMULATION RIG

Key findings:

Fig. 8 presents the results from the experiments, identifying the suitability of the sensor to detect colon like contractions generated by a physical simulation of the colon. The graphs show, detection of one actuator contracting, detection of both actuators contracting, a timed offset between actuators contracting, and finally detection of contraction with partial obstruction of the actuator. This final experiment represents a situation where muscle may be damaged and not contract uniformly. The results from this initially proof of concept have shown potential for future development. In this simulated situation the sensor shows capability of detection contractions, and identifying where contractions are not uniform. This lends itself well to assessing patients' muscular action after repairing of muscle or tissue.

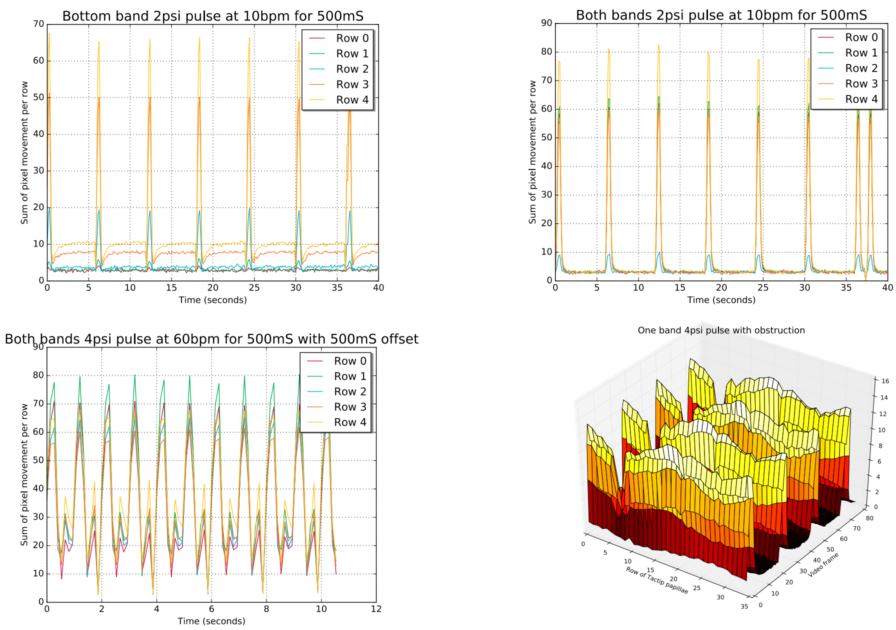

FIGURE 6 POST PROCESSED DATA FROM INTEGRATION EXPERIMENTS

[1] Winstone, Benjamin, et al. "Biomimetic Tactile Sensing Capsule." Biomimetic and Biohybrid Systems. Springer International Publishing, 2015. (Awaiting publication August 2015)