Push Technology – The Computer Meets the FSR

John Cleary, Phil Morrison,
Peter Brook
Otago Polytechnic
Dunedin, New Zealand
johnc@tekotago.ac.nz

ABSTRACT

Computers have long been used to capture the output of transducers that sample real-world signals. Force sensing resistors (FSR's) are polymer thick film devices that exhibit a decrease in resistance with an increase in the force applied to the active surface. They are flexible and non-intrusive making them ideal to insert into existing appliances, clothing and sporting equipment. This paper describes a method of calibrating such sensors using a networked Programmable Logic Controller where thousands of regular, measured blows were applied to the FSR's. The outputs of the FSR's were compared to those of a strain gauge so that drift in output compared with time and temperature could be calibrated. Our results indicated that FSR's are reliable and reasonably stable for certain applications. A survey is given of topical uses as well as some current FSR projects which include knowing how much milk is in your fridge as well as measuring, via wearable computers, who is doing all the pushing in the Otago Highlanders front row.

1. INTRODUCTION

There are many uses within industry for cheap, reliable and robust sensors. The present paper describes the preliminary work, in assessing the suitability of a thin film sensor (FSR- force sensitive resistor) to record in normally inaccessible, difficult or hazardous environments. This new technology creates solutions in engineering, robotics, biomechanics and within industry.

The FSR transducer is a tactile sensor that discerns variations in the applied force. The harder you press the greater the resistance decreases. Hence the nickname "the electronic gas pedal". The technology was first developed for musicians who wanted their music to become louder when the keyboard was pressed harder and softly with a lighter key press.

FSR's are temperature, chemical and moisture resistant. They are insensitive to vibration and electromagnetic fields. They contain no moving parts and are robust under repetitive use. They are thin as a business card (0.1mm) and have been designed to detect forces as light as a fingertip or as large as the weight of a vehicle. They are also responsive to variations in applied pressure.

Figure 1

Basic FSR

The sensor activation threshold can be adjusted using simple electronics. They also operate at much lower currents and cost in comparison to similar sensing devices.

Competing and older technologies are the piezopolymers, ceramic strain gauges and the conductive rubbers. The piezopolymers are susceptible to unwanted acoustic and vibration pickup. Piezopolymer sensors also require more complex electronic interfaces. FSR is also more rugged and costs considerably less than strain gauges. Conductive rubber exhibits more hysteresis and again is more expensive than FSR.

A basic FSR is two polymer sheets laminated together. One sheet is coated with interdigitating electrodes; the other sheet is coated with semiconductive material. When a force is applied to the FSR, the semi conductive material shunts the interdigitating electrodes to a greater or lesser degree according to the applied force.

With particular designs of FSRs it is possible not only to measure the force but also the position of that force. The spatial resolution can be as small as ~0.5mm.

Overall the sensor's extreme thinness and high spatial resolution make it minimally intrusive and a good choice for measuring dynamic pressure distributions. As a consequence, there are a number of potential applications our School is currently developing for FSR technology (Mann, *et al.*, Mann, *et al.* & Sherriff *et al.* 2001).

As a relatively new technology there are limited examples within the literature on the current usage of FSR sensors. Automakers have monitored clamping forces and sealing pressures to analyse the effectiveness of engine gaskets. The 2D and 3D generated images depict the dynamic pressure changes of a centre fire ring seal during assembly, simulated combustion and relaxation. Once the tests were completed the pressure distribution data enabled the enhanced design of the engine gasket and assembly specifications (Malacaria, 1998).

Measurement of the real-time force and pressure distribution at the contact area of pinch rollers can be made during machine setup. The pressure distribution indicates the roller nip and permits the fast adjustment of contact pressure and area. Such tools help reduce machine setup time and minimise product scrap (Malacaria, 1998).

Bolted joints are a common method used in manufacturing. In many cases this joint is the key link to structural integrity of the mechanism. The use of FSR sensors provides a way to investigate the pressure distribution in the joint and therefore the detection of uneven torquing patterns leading to premature failure (Malacaria, 1998).

Other successful applications include evaluating the effects of high-speed input; the analysis of body pressure in seating; and studying the pressure distribution between caster wheels and flooring materials (Malacaria, 1998).

Application of FSR has occurred across a wide field of medical interest. Their steady employment is a consequence of their suitability for recording forces in normally difficult or inaccessible situations for conventional recording. Rehabilitation aids and clinical measurement, based on FSR, are increasingly more common in the health sciences. In Melbourne a gait re-education device has been designed. The audible feedback device is used to encourage a more normal heel strike pattern in walking (Dennison, 1993). Plantar pressure during gait with different shoes on various surfaces has been evaluated in normal and clinical situations (Cobb & Claremont., 1995; Yang *et al.*, 1991). One of the most common uses has been in the recording of hand function under a variety of situations. A major advantage of FSR over competing technologies is that they can be fitted to the device or the hand (by glove) with minimal effect on the biomechanics of grip (Castro & Cliquet, 1997; Freivalds, 1995; Knudson & White 1989; Lee & Rim 1991; Rice *et al.*,1998; Yun *et al.*,1995). Other uses have involved the analysis of bedding (Kohle) and amputees (Childress *et al.*, 1999;Tura *et al.*, 1998).

The variety of research utilising FSR has been outlined. Why do we need this type of device? Its characteristics of being small, unobtrusive, capable of realtime sampling, cost effectiveness and durability make it an ideal candidate for the initial investigation. The alternatives are often expensive, fragile, bulky and/or technically difficult within a real world application. The purpose of the present study is the evaluation of the FSR dynamic and static qualities in a standard laboratory testing situations. Our team wished to quantify the characteristics of FSR's prior to integration in product prototypes.

2. METHODOLOGY

2.1 Apparatus

Industry has common standards for outputs of transducers. One of these is the 4-20mA current loop where 4mA represents 0% and 20mA represents 100% of whatever is being sensed eg temperature,

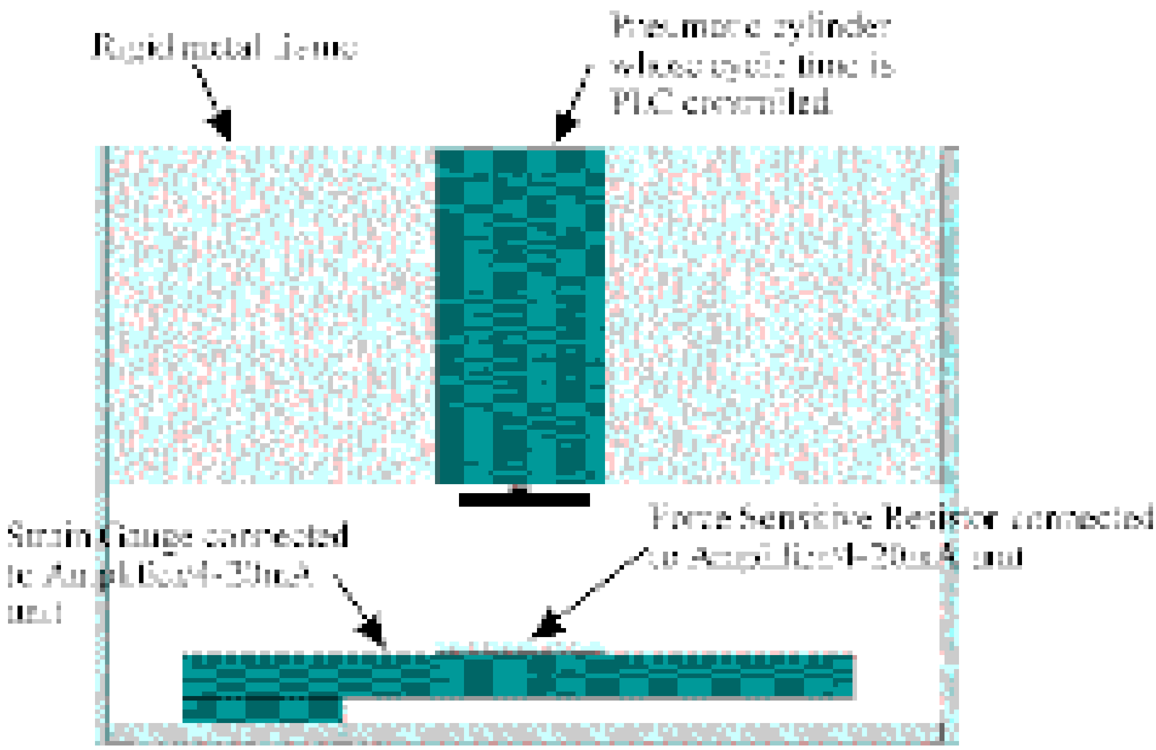

Figure 2

Schematic Recording Setup

pressure. The advantage of this type of output is its ability to interface directly to data logging equipment. This information can then be scaled and presented directly in engineering units in real time.

2.2 Procedure

The InterLink Force Sensistive Resistor 1½ " square (FSR), was fixed on a cantilever precision transducer PT1000 15kg strain gauge. A current to pressure transmitter varied the supply air pressure to a pneumatic cylinder, in set amounts. An Allen Bradley programmable logic controller (PLC) was used to control the cycle time of the cylinder, as well as converting the 4-20mA strain gauge, FSR and air pressure transducer outputs to digital format.

The data from the PLC was logged continuously over a number of days and graphically displayed using WonderWare InTouch Process Visualisation software over a Novell network. This data was then converted to a CSV file for statistical analysis. In this system, the PLC controlled the cylinder causing it to stroke down. This applied pressure on the FSR in series with the strain gauge. The strain gauge was used as the standard, and the FSR was tested and compared against this. The sensor configurations have been tested under a randomised variety of loads. The future intentions are to also assess batch variations, temperature influences, hysteresis, wear and time dependent effects.

3. RESULTS

Preliminary results are presented (figures 2 and 3).

Although too early to quantify precisely, there is evidence that the FSR sensors exhibit some reproducibility problems, display variations across different batches, show small variation with temperature, and demonstrate "warm-up" characteristics. These early findings are largely consistent with Smith & Hudson (1994).

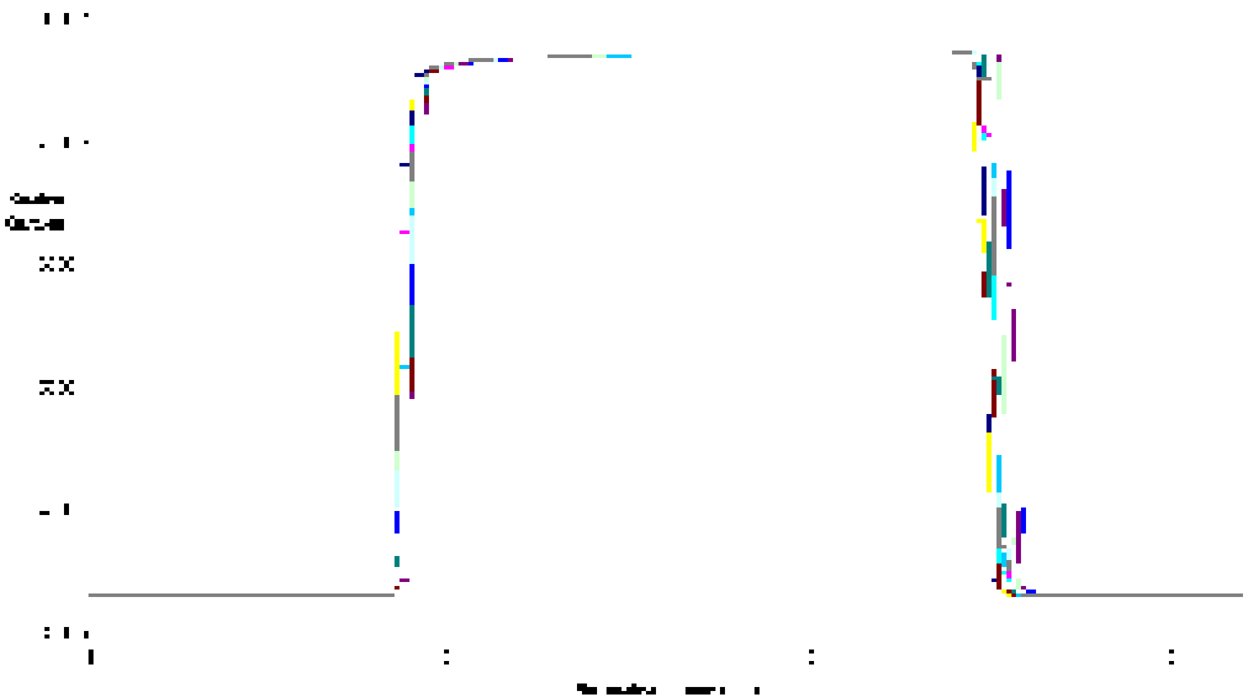

Figure 3

An example of FSR- Force time variances

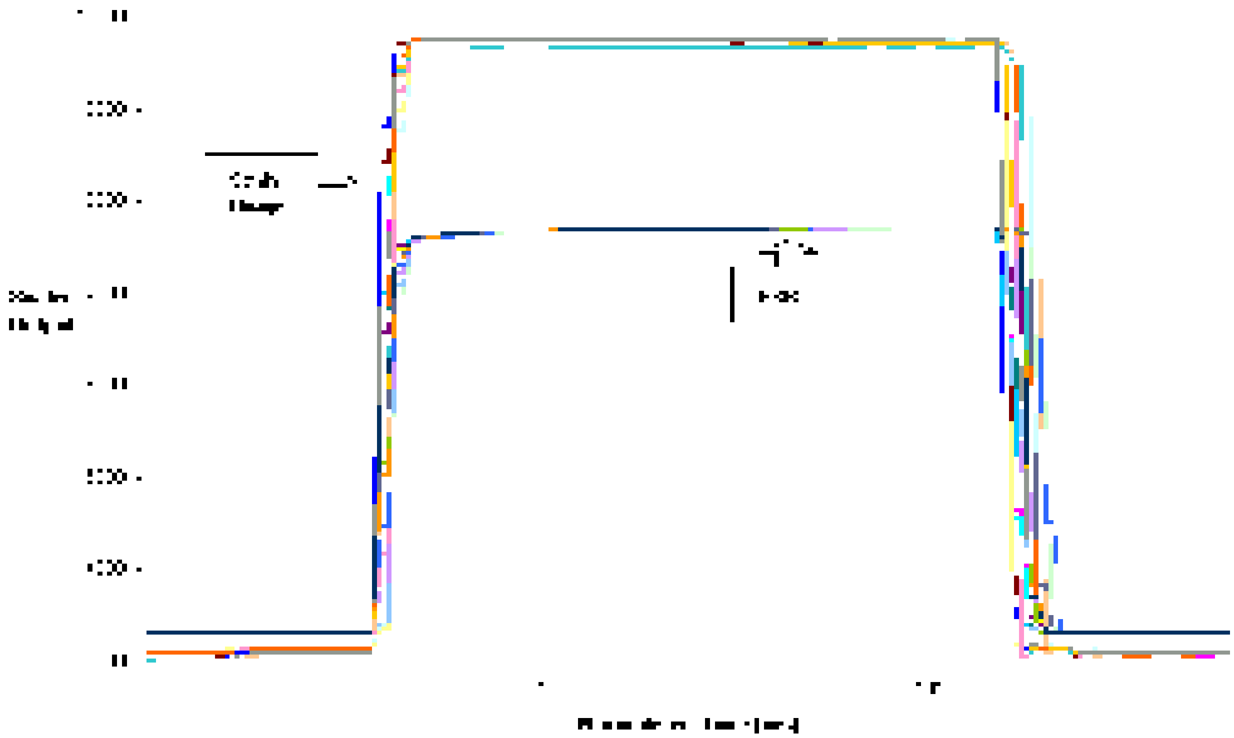

Figure 4

An example of sensors- Force time variances

4. CONCLUSION

Before any potential applications can take place it was essential to construct an FSR interface that was reliable and valid. From there we will be able to more accurately determine the actual responses of the FSR sensors under a variety of test conditions. In this way we will be able to better determine which applications are best suited for future considerations.

REFERENCES

Castro, M. C. & Cliquet, A. J. (1997). "A low-cost instrumented glove for monitoring forces during object manipulation". IEEE Transactions on Rehabilitation Engineering, 5(2), 140-147.

Childress, D. S., Weir, R. F., Heckathorne, C. W., Edward, C. G., Uellendahl, J. & Bertos, Y. "Generalized EPP position controller for electric-powered upper-limb prostheses". Online. http://pele.repoc.nwu.edu/progress/jrrd.dva.9809.EPPCont.html. Accessed 6th August 1999.

Cobb, J. & Claremont, D.J. (1995). "Transducers for foot pressure measurement: survey of recent developments". Medical & Biological Engineering & Computing. 22(4):525-532.

Dennison, M. Personal communication. (Nov 15, 1993) Department of Biomedical Engineering: Caulfield General Medical Centre.

Freivalds, A.(1995) "EMG Study: Feel and weight of handles". Online. http://www.thoughttechnology.com/ergonews.html. Accessed 6th August 1999.

Knudson, D. V. & White, S. C. (1989). "Forces on the hand in the tennis forehand drive: application of force sensing resistors". International Journal of Sport Biomechanics, 5(3), 324-331.

Kohle, R.C. "DermaSafe mattress base line study" Online. http://www.sns-access.com/~bobk/dermarep.html, Accessed 5 Mar 1999.

Lee, J. W. & Rim, K. (1991). "Measurement of finger joint angles and maximum finger forces during cylinder grip activity". Journal of Biomedical Engineering, 13(2), 152-162.

Malacaria, C. F. (1998). "A thin flexible matrix-based pressure sensor". Sensors_Magazine, Online.

http://www.sensormag.com/articles/thi0998.html, Accessed 5 Mar 1999.

Mann, S., McGregor, G., & Brook, P. (2001) "Industrial IT Project". Poster, NACCQ Conference Proceedings, 2001.

Mann, S., Brook, P. & Doonan, A. (2001) "eFridge: Everyday Internet Appliance". Poster, NACCQ Conference Proceedings, 2001.

Rice, M. S., Leonard, C. & Carter, M. (1998). "Grip strengths and required forces in accessing everyday containers in a normal population". American Journal of Occupational Therapy, 52(8), 621-626.

Sherriff, L., Sherriff, R., Forscutt, O., Ho, S. & Mann, S. (2001). "Smart-top: Athlete Monitoring for High Impact Sport." Poster, NACCQ Conference Proceedings, 2001.

Smith, B. P. & Hudson, W. B. (1994). "The use of Force Sensing Resistors for muscle force measurements". Biomedical Sciences Instrumentation, 30, 153-158.

Tura, A., Lamberti, C., Davalli, A. & Sacchetti, R. (1998). "Experimental development of a sensory control system for an upper limb myoelectric prosthesis with cosmetic covering". Journal of Rehabilitation Research & Development, 35(1), 14-26.

Yang, J.F., Stephens, M.J. & Vishram, R. (1998). "Infant stepping: a method to study the sensory control of human walking". Journal of Physiology. 507(3), 927-937

Yun, M. H., Kotani, K. & Ellis, D. (1995) Using force sensitive resistors to evaluate hand tool grip design. Online. http://www.cms.dmu.ac.uk/General/hci/hcibib/HTML/HFS/Yun92a.html. Accessed 6th August 1999.