Sensor Array Calibration using a Neural Net Algorithm

Objective

➔ Simulate the behavior of a precise sensor with an array of lower resolution sensors after calibration of the array against the precise sensor.

Possible because of the batch fabrication nature of MEMS technology.

Neural Net Algorithm

➔ Neural Net is a non-linear algorithm which can be used to re-generate a function after training the Net with the function behavior at known points.

➔ The Net can then be used to estimate the function at unknown points (with a certain error).

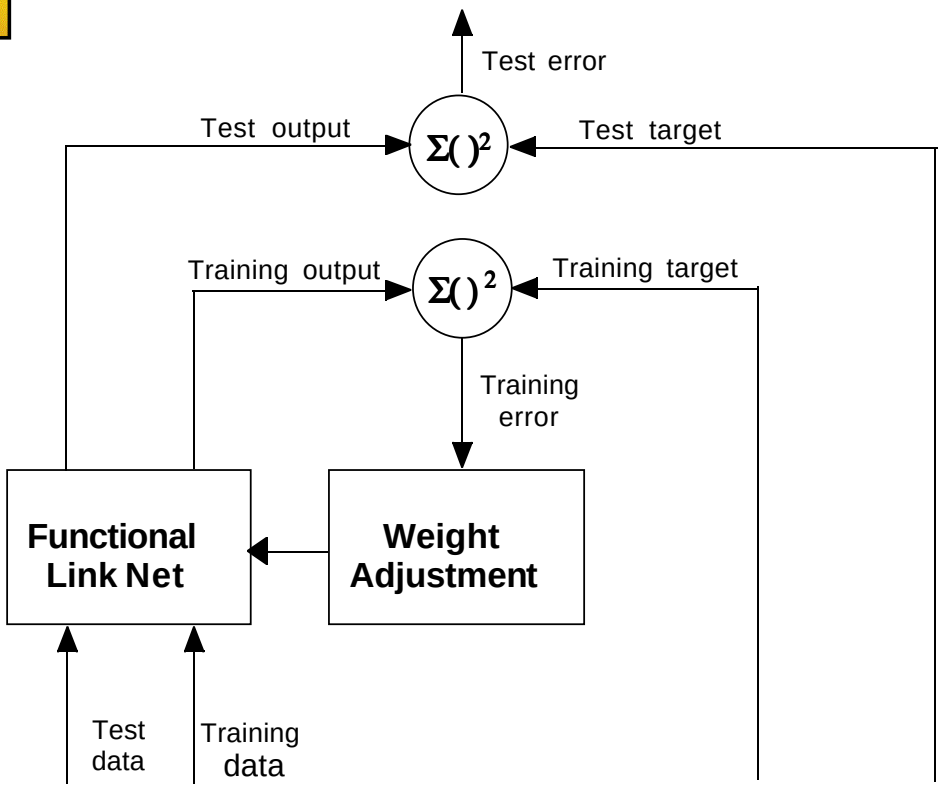
➔ The sensor array calibration algorithm is:

Use two sets of data, one for training (known) and the other for testing (unknown).

Minimize the output error during training of the sensor array against the precise sensor.

Stop when testing error reaches a minimum.

Training Procedure



Functional Link Net

- Functional link net is a type of neural net with Gaussians as basic transform functions.
- The output of the net is the sum of a bias and the individual Gaussian function outputs multiplied by their corresponding weights.
- To minimize the error at training points, the weight and bias are adjusted.

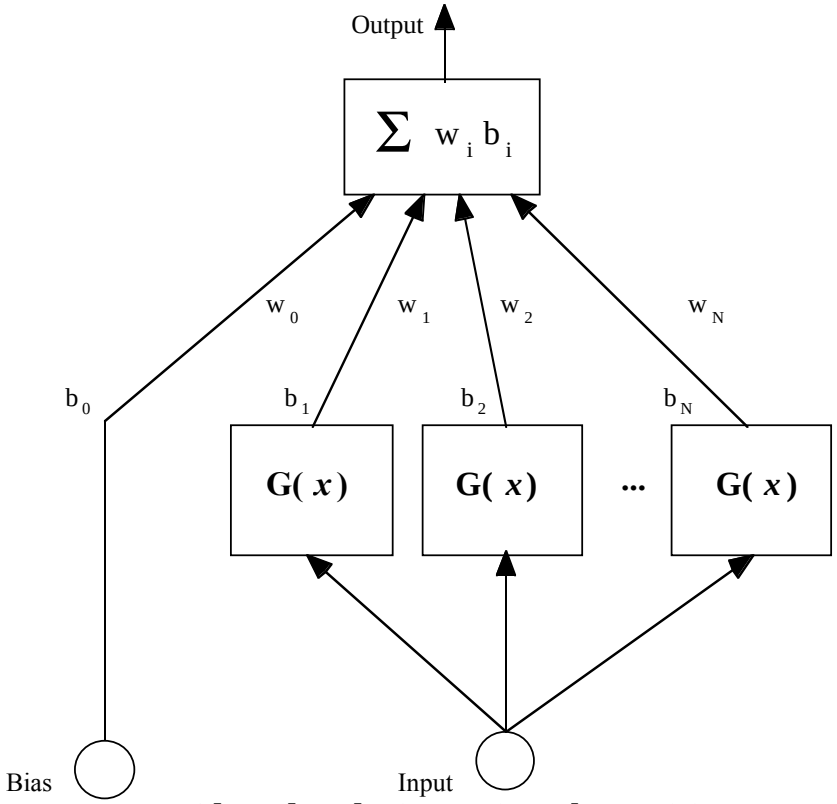
$$\text{Output,j} = \text{bias} + \sum(W_i \times b_i) \qquad i=1,2,...,n$$

b_i — output of each Gaussian function

W_i — weight corresponding to each Gaussian function

$$\text{Error} = \sum(\text{Output,j} - \text{training data})^2, \quad j = 1, 2,...,m$$

Functional Link Net

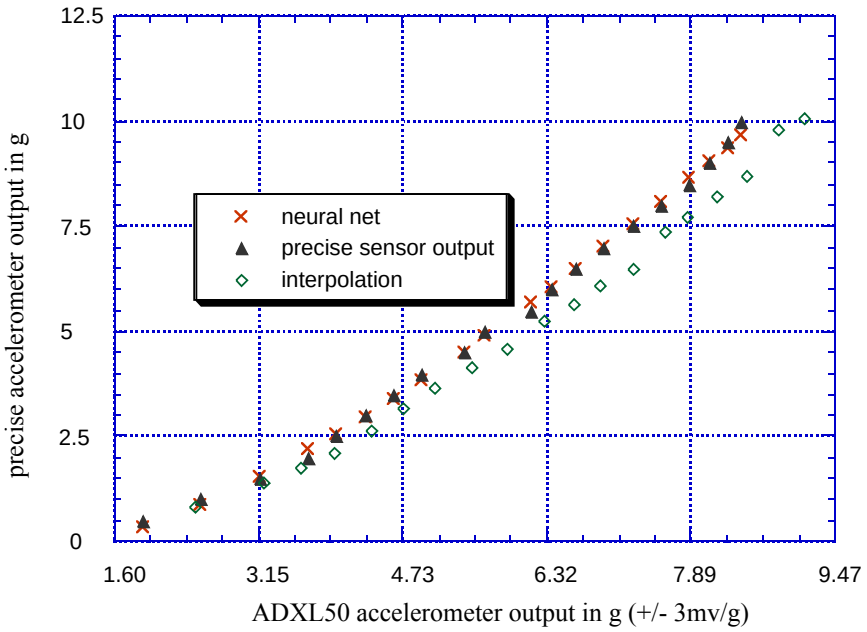


Experimental

- A shake table housing one precise acceleration sensor and a PC board with 6 ADXL50 accelerometers. Data is obtained as a function of vibration amplitude at a fixed vibration frequency.
- A second experiment uses 7 low resolution and a precision thermistor placed in deionized water bath and subjected to a temperature ramp.
- For each experiment, two sets of data are obtained — one for training and the other testing.

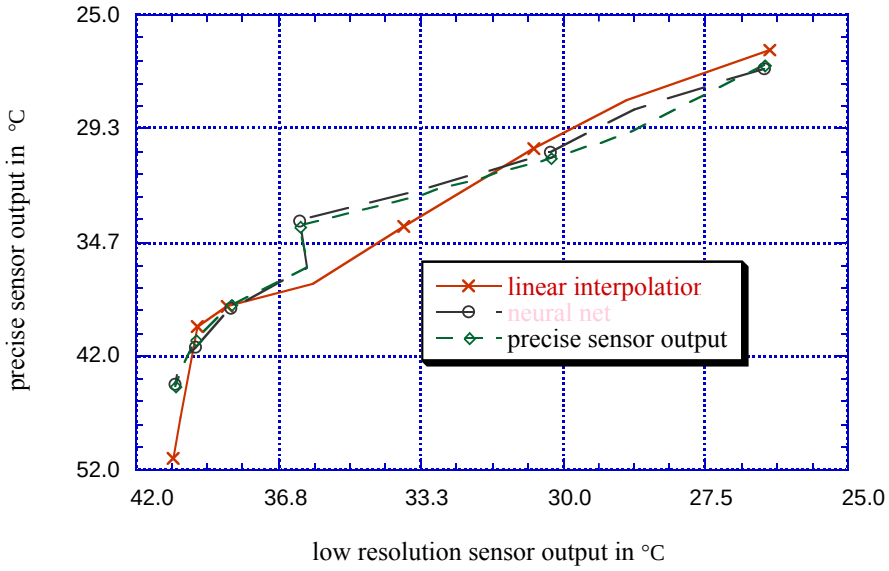
Neural Net versus Linear Interpolation

acceleration sensor data



Neural Net versus Linear Interpolation

temperature sensor data



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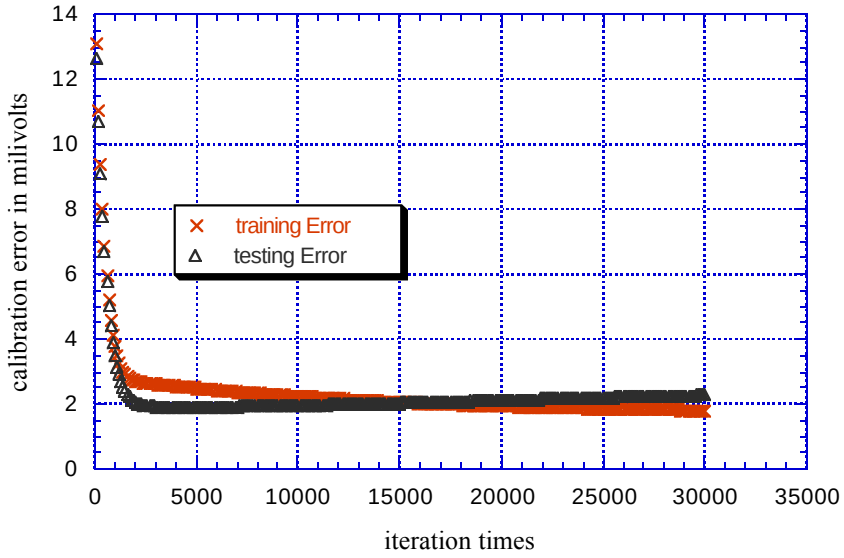
Calibration Error of Accelerometer Array



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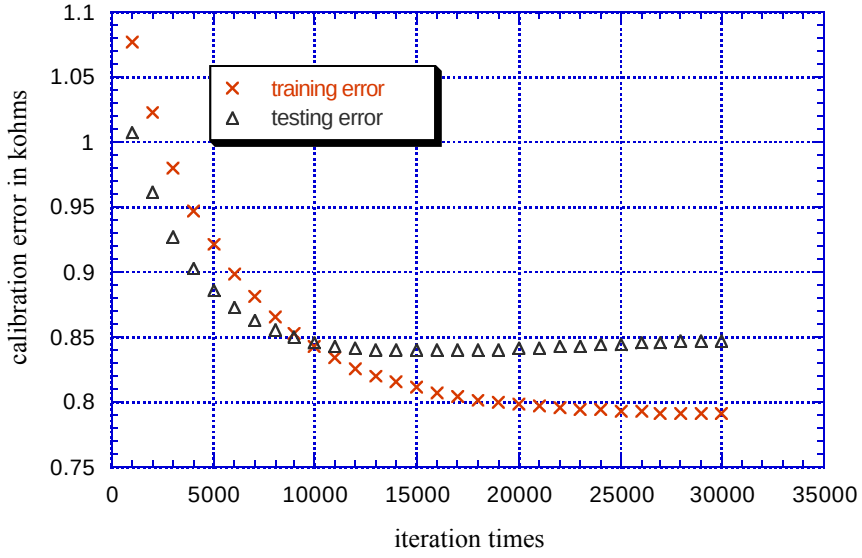
Calibration Error of Temperature Sensor Array



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Discussion

The sensor performance may be improved, but with the following limitations:

- ➔ Individual sensor behavior must be repeatable.
- ➔ Training procedure is sensitive to initial training data and training parameters.
- ➔ After a certain period of training, the output error tends to reach a plateau.

Comparison with other people's research

The research conducted here at Case Western Reserve is original in this sensor array calibration aspect,because:

- ➔ many identical sensors are used to measure the ***same*** physical quantity, while other reported research is oriented in using many sensors to measure different physical quantities at different locations.

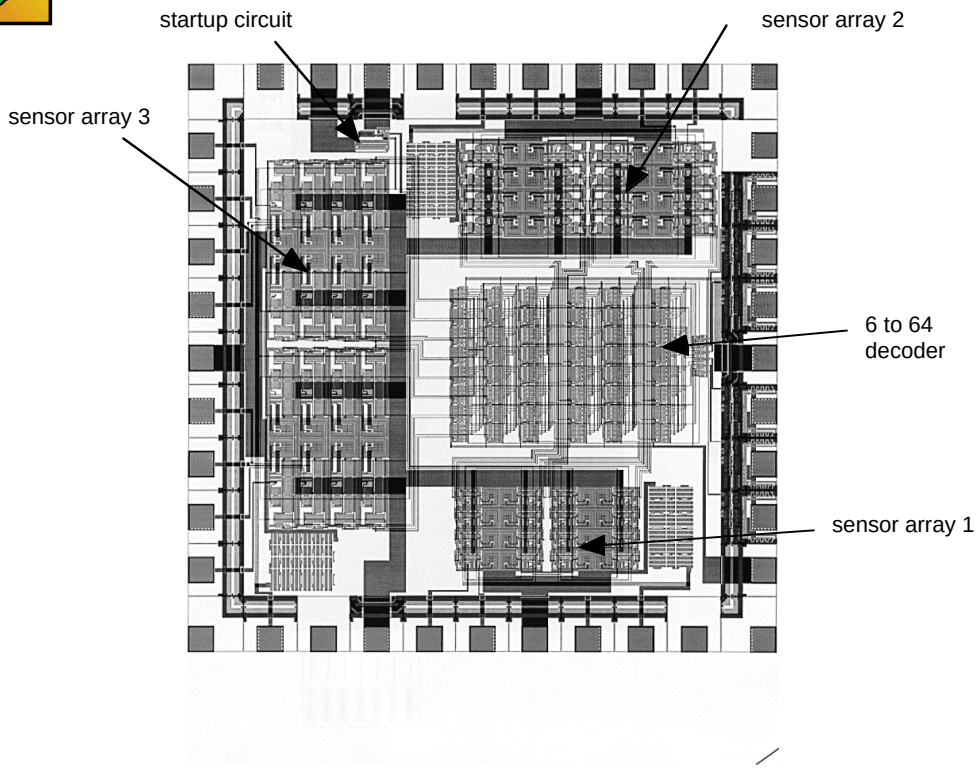
Discussion (cont'd)

The training of temperature sensor array is not very successful, because:

➔ The training is stuck at some local minima due to the initial parameter chosen.

➔ Training set has not represent the behavior of the sensor very well.

Temperature sensor chip



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Temperature sensor chip description

The temperature sensor chip shown has three sensor arrays on it. Each sensor array consists of 16 sensors. The only difference of the three sensor arrays is the size. The sensor in array three is the largest while sensors in array one is the smallest. With a certain fabrication error, the larger the size of the sensor, the smaller the relative error for that sensor. We can use the large sensor to serve as a precise sensor for the calibration of small sensors. A digital decoder is used to select one of the 48 sensors and data will be collected from the output port.

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