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ONR

To: Dr. Joel Davis

From : Dan Greenwood

Subject: Status Report on:

Neural Networks and Robotics Applied to the Non-destructive Inspection of Aircraft; N00014-91-C-0095.

The past two months on the project were devoted to the following tasks"

1. Flaw Recognition:

We are converting the in phase and quadrature measurements into an image and then using the image to classify fault or no fault eddy current. This has been done using old OCR features developed to recognize handwritten numerical characters which are applicable to this situation. The raw data was first smoothed out by taking the average of the nearest 10 measurements, then plotted on a 50 by 50 grid. The X axis is the in phase measurement normalized to accommodate the maximum and minimum in phase values in the data set. The same was done for quadrature values on the Y axis.

The data set used consists of 18 bolt measurements, each of which were scanned with three different frequencies. There is also a set using different frequency intervals, and a set from a different scanner altogether. I have only looked at CRS measurements up to this point (Specimens 1 and 3). The same bolt is measured at different frequencies in the theory that one frequency carries the geometry signal while another carries both the geometry and the flaw information. Thus the flaw data can be extracted from the combination of frequencies. The result of this situation is an input set of the features extracted from the three frequency graphs, this turned out to be 18 patterns with 171 inputs and one output. The training set was learned well within 5,000 input presentations, but generalization was not above chance level. This appears to be an example of overfitting, what would help would be many more training patterns or a reduced input set to give the network a real chance at generalization.

In the future it would be useful to look at the signals one at a time rather than classifying the end product image. This would reduce inputs and perhaps better isolate the fault section of the signal. More systematically prepared examples would also as usual be useful. Another thing worth looking at would be the data processed at SRI. They have some preprocessing method for extracting the flaw signal from the geometry signal, and this data would perhaps be very useful.

The network that has shown the greatest promise up to this point uses the individual input representation rather than the graph representation. The CRS sensor value is smoothed out then three features are extracted, one feature corresponding to the current sensor reading, one feature for long term change in value, and one feature for short term change in value. The network is then simultaneously given these features at a certain position for in phase and quadrature measurements at all three of the frequencies taken for a total of 18 inputs. This input is trained as fault if the position is close to a flaw, otherwise is trained as no fault. The network learned the training set to within 0.0020 RMS error, and then was tested on a no fault case and a case with a 0.20 in flaw. It was able to correctly identify the flaw region with 39 fault classifications in a row on the first rotation around the bolt and 28 fault classifications on the second time around. The maximum number of incorrect fault classifications was 7 and the maximum number missed classifications that should have been fault was 12. This leaves a wide cutoff range where the network can identify a true flaw.

2. Robotics:

An efficient path planning method for collision avoidance has been developed. Fast path planning is achieved by decomposing the 3-dimensional space into a number of 2-dimensional subspaces. A method is devised to work directly with arm postures (configurations) instead of dealing with individual joint angles. These two aspects, namely decomposition and posture control, greatly speed up the path finding procedure and make it possible to perform near real-time planning in a moderately cluttered environment.

A backpropigation neural network has been utilized to determine the optimal arm postures for preventing unnecessary large arm movements during path execution. Training the network has been accomplished using SAIC's ANSim neural network simulation software. Training has been successful on up to 13 arm postures. A test program has shown that the network can generalize for various obstacles.

The path planner software is comprised of several separate programs. The functions of these programs are described in a technical report. The path planner was implemented using a PUMA 562 robot. The obstacles consisted of a number of boxes on the floor, suspended from overhead, or floating in space. The obstacle data can be created and stored in a file or read from the vision system. Several experiments were carried out to determine the effectiveness of the planner. The planner determined and executed a collision free path in a "block world" environment extremely fast.

3. Data Acquisition:

Meetings were held at McDonnell Douglas, McClelland AFB, and Physical Research Inc., manufacturers of Magneto-Optic Crack Detectors to assess the utility of our research and plans for prototyping during Phase II. Discussions have begun with United Technologies concerning the use of our research for a large Air Force NDI program. Prospects for Phase III follow-on look promising.