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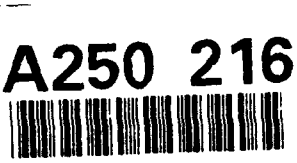

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13. ABSTRACT

The training problem for feedforward neural networks is nonlinear parameter estimation that can be solved by a variety of optimization techniques. Much of the literature on neural networks has focused on variants of gradient descent. The training of neural networks using such techniques is known to be a slow process with more sophisticated techniques not always performing significantly better. It is shown that feedforward neural networks can have ill-conditioned Hessians and that this ill-conditioning can be quite common. The analysis and experimental results lead to the conclusion that many network training problems are ill-conditioned and may not be solved more efficiently by higher order optimization methods. The analysis are for completely connected layered networks, they extend to networks with sparse connectivity as well. The results suggest that neural networks can have considerable redundancy in parameterizing the function space in a neighborhood of a local minimum, independently of whether or not the solution has a small residual.

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1 RELIABILITY MODELS BASED ON COMPARISONS AMONG USED ITEMS

In the usual nonparametric classes of distributions used to model aging, items or systems which are new play a distinguished role. Each of such classes is defined in terms of stochastic comparisons between new items and one or more used items. There are a number of reliability applications in which the more relevant comparison is between used items of various ages. The prototypical example of this is a situation in which replacement parts in a given system are drawn from a pool of used parts. One such replacement policy is used, for example, by the Air Force under the name of cannibalization. In such a situation, one would wish to know whether an item of age t_1 tends to be better or worse than an item of age t_2. This leads us to consider nonparametric classes of distributions based on stochastic ordering constraints on residual lifetimes. A survival function S is better at age t_1 than at age t_2 ($t_1 B t_2$) if

$$\frac{S(x+t_1)}{S(t_1)} \geq \frac{S(x+t_2)}{S(t_2)} \quad \text{for all } x \geq 0. \tag{1.1}$$

Of immediate interest are the closure properties of the class of distribution functions defined by (1.1). As reported in the First Annual Progress Report, the principal investigator has proven the following theorem.

Theorem 1.1 *The class of distribution functions defined by (1.1) is not closed under mixtures nor under convolutions, and a necessary condition for S to satisfy (1.1) is that $r_F(t_2) \geq r_F(t_1)$ where r_F is the failure rate of F.*

Another area of primary interest in connection with the class of survival functions defined by (1.1) is the estimation of the survival function based on a sample. For this purpose, note that expression (1.1) may be written in the form

$$S(x) \leq \frac{S(t_2)}{S(t_1)} S(x-(t_2-t_1)), \quad x \geq t_2 \tag{1.2}$$

This expression motivates the study of the estimator satisfying the recursion

$$\hat{S}(x) = \begin{cases} S_n(x), & 0 \le x \le t_2 \\ \min\left\{S_n(x), \frac{\hat{S}(t_2)}{\hat{S}(t_1)}\hat{S}(x-\Delta)\right\}, & x > t_2 \end{cases} \tag{1.3}$$

where $\Delta = t_2 - t_1$ and S_n represents the empirical survival function.

As it was reported in the first annual progress report, in joint work with F.J. Samaniego (U.C. Davis) and D.M. Reneau (Cal. State Stanislaus), it has veen verified that the estimator $\hat{S}$ in (1.3) is a well defined survival curve, belongs to the t_1Bt_2 class, and has a fairly straightforward closed-form representation.

In the second annual progress report dated 1/28/91, it was conjectured that the estiamtor given by (1.3) satisfied the inequality

$$\sup_x |\hat{S}(x) - S(x)| \le \sup_x |S_n(x) - S(x)| \tag{1.4}$$

where S represents the true survival function and S_n represents the empirical survival function. As a consequence of the conjecture, the strong uniform consistency of the estimator (1.3) would follow easily.

We were unable to show (1.4) but a different approach yielded the strong uniform consistency of (1.3). The details of this result are contained in Theorem 2 of the enclosed Tech. Report No. 213 of the Intercollege Division of Statistics of the University of California at Davis which has been accepted by *Naval Research Logistics* pending some editorial changes.

2 ESTIMATION OF A DISTRIBUTION UNIFORMLY STOCHASTICALLY SMALLER THAN A STANDARD

This area of research , although not part of the contract, is included here because it arose in connection with some ideas related to Section I, and because the idea presented here came to fruition while the principal investigator was drawing partial salary from the contract.

Let F and G be distribution functions. Then F is said to be uniformly stochastically smaller than G, $F <_h G$, if

$$\overline{G}/\overline{F} \quad \text{is nondecreasing,} \tag{2.1}$$

where $\overline{G} = 1 - G$ and $\overline{F}$ is similarly defined.

When F, G are absolutely continuous, (2.1) is equivalent to $r_F \geq r_G$ for all x, where r_F and r_G are the failure rates of F and G respectively. Thus, a prototypical application of survival functions satisfying (2.1) is a experiment performed under conditions known to be more stressful than the "optimal" conditions used to test a system in the laboratory for example.

In Rojo and Samaniego (1989), the nonparametric maximum likelihood estimator of a survival curve satisfying (2.1) with G known was derived and studied. More specifically, it was shown that the nonparametric maximum likelihood estimator of $\overline{F}$ is given by

$$\hat{\overline{F}}(x) = \overline{G}(x)\overline{F}_n(x). \tag{2.2}$$

It is clear from (2.2) that $\hat{\overline{F}}$ is inconsistent for $\overline{F}$. This work which acknowledges AFOSR support, has appeared in *Statistics and Probability Letters* (1991), **11**, 267-271 and a reprint of the paper is enclosed with this report.

In the previous annual report, an alternative to the m.l.e. estimator was proposed. As a new result, it has been shown that

$$\hat{\overline{F}}_n(x) = \inf_{0 \leq y \leq x} \frac{\overline{G}(x)}{\overline{G}(y)} \overline{F}_n(y) \tag{2.3}$$

is uniformly and strongly consistent for the true $\overline{F}$ at an optimal rate. In fact, it has been shown that

$$\sup_x |\hat{\overline{F}}_n(x) - \overline{F}(x)| \leq \sup_x |\overline{F}_n(x) - \overline{F}(x)| \tag{2.4}$$

where $\hat{\overline{F}}_n$ is given by (2.3), $\overline{F}_n$ is the empirical survival function, and $\overline{F}$ is the true survival function. As a consequence of (2.4), it is shown that $\overline{F}_n$ is inadmissible for a wide class of loss functions. Simulations have shown that our estimator also beats $\overline{F}_n$ in mean squared error. This work which acknowledges AFOSR support and which represents joint work with F. Samaniego is under review for possible publication. Technical Report No. 203 which is enclosed with this final report, and which acknowledges AFOSR support, gives the details of the above work.

3 HONORS AND AWARDS RECEIVED IN THE LAST TWO YEARS

a) Refereed various articles for *Communications in Statistics*, *Metrika*, *JASA*, *Journal of the Electrochemical Society*, and proceedings of a NACE symposium.

b) Member of NSF panel to review fourteen proposals for the Statistics and Probability program.

c) Refereed other various NSF proposals.

d) Promoted to Associate Professor with tenure, effective Sept. 1, 1990.

4 GRADUATE STUDENTS AND TIES WITH OTHER RESEARCHERS

Although AFOSR does not provide salaries for graduate students under the contract, the matching cost contribution by the University of Texas at El Paso has provided one graduate student for each semester of the academic year. The students work a total of 10 hours per week under the direction of the Principal Investigator. Up to now, Victor Carrillo and Alejandro Ortiz, both Mexican citizens, have worked for the project.

The professional ties established with Francisco J. Samaniego (U.C. Davis), Dana M. Reneau (Cal. State Stanislaus) and Arturo Bronson (Metallurgical Engineering Dept., UTEP)

continue to be fruitful.

5 PUBLICATIONS OF JAVIER ROJO IN THE LAST TWO YEARS

*1.- J. Rojo, and F. J. Samaniego (1989). "On Nonparametric Maximum Likelihood Estimation of a Distribution Uniformly Stochastically Smaller than a Standard", Technical Report # 183, Intercollege Division of Statistics, University of California at Davis.

2.- J. Rojo, D. Vallejo-Rodriguez, and A. Bronson (1991). " The Ohmic Potential of Diamond-Shaped Scratches Acquired from During Scribing of Electrodes", Proceedings of the Symposium on Wear-Corrosion Interactions in Liquid Media, Alberto Sagueq and E. I. Meletis, eds., Minerals and Metals Society, 37-46.

3.- J. Rojo (1992). "A Pure-Tail Ordering Based on the Ratio of the Quantile Functions", In Press, *The Annals of Statistics*, March 1992, 13 pages.

4.- J. Rojo, and G. Zhong-He (1990). "On New Properties and Characterizations of the Dispersive Ordering", *Statistics and Probability Letters*, **11**, 365-372.

*5.- J. Rojo, and F. J. Samaniego (1990). "On Nonparametric Maximum Likelihood Estimation of a Distribution Uniformly Stochastically Smaller than a Standard", *Statistics and Probability Letters*, **11**, 267-271.

*6.- J. Rojo, and F. J. Samaniego (1991). "On Estimating a Survival Curve Subject to a Uniform Stochastic Ordering Constraint". Submitted for publication.

7.- J. Rojo, D. Vallejo-Rodriguez, and A. Bronson (1991). "The Effect of the Scratch Shape on the Ohmic Potential Created During Scribing of Electrodes". *Journal of the Electrochemical Society*, **138**, No. 5, 1364-1368.

*8.- D. M. Reneau, J. Rojo, and F. J. Samaniego (1991). "On Estimating Survival for Reliability Models Based on Comparisons Among Used Items", Tech. Report No. 213, Technical Report Series of the Intercollege Division of Statistics, University of

California at Davis. This paper has been tentatively accepted for publication by *Naval Research Logistics*, pending some changes.

9.- P. Goldstein, L. Magnano, and J. Rojo (1992). "Effects of Dimethyl Sulfone (DMSO2) on Early Gametogenesis in *Caenorhabditis elegans*: Ultrastructural Aberrations and Loss of Synaptonemal Complexes from Pachytene Nuclei", In press, *Reproductive Toxicology*.

*10.- J. Rojo (1992). "On the Preservation of Some Pure-Tail Orderings by Reliability Operations", Submitted for publication.

* Acknowledges AFOSR support.