P. J. Antsaklis, John Moody and the ISIS Research Group, Review of the video tutorial "Adaptive Signal Processing and Adaptive Neural Networks" by Bernard Widrow, IEEE Transactions on Neural Networks , Vol. 5, No. 5, p 859, September 1994.

Adaptive Signal Processing and Adaptive Neural Networks—Bernard Widrow. *Reviewed by Panos Antsaklis, John Moody, and the ISIS Research Group.*

Bernard Widrow is a pioneer in adaptive and learning systems. His early work, which includes the well-known LMS algorithm, dates from the late 50's and early 60's. He has had a continuous record of significant technical contributions during his nearly four decade-long career. Appropriately, this two-hour video on adaptive filters and neural networks is in the "Neural Networks Pioneer Series," sponsored by the IEEE Neural Networks Council.

The video is delivered by Widrow as a lecture using transparencies but is occasionally punctuated with video segments of live action and computer simulations. The lecture is broken into two hour-long segments. The first hour concentrates on Widrow's earlier work in adaptive filters, including the LMS algorithm and the adaptive linear neuron (Adaline). The second hour concentrates on neural networks and includes a brief history, as well as an overview of neural network training algorithms and applications of neural networks to nonlinear control. A summary of the topics covered in the two parts is given in the paragraphs below.

VIII. Part I: Adaptive Signal Processing

Widrow starts the video lecture by introducing an adaptive linear combinatorial system which outputs a weighted sum of its inputs. It is stressed that this device is the major building block of all adaptive filters and neural networks. The device is shown to contain the potential for adaptation by introducing an error equation, showing that the error is a function of the filter weights, and then deriving the least mean squares (LMS) algorithm that Widrow and his student Hoff developed in 1959. Widrow then shows how the basic linear adaptive filter can be modified to construct a simple artificial neuron with the addition of the a threshold (signum) function at the output (so the device outputs are restricted to ± 1) or can be made into an adaptive digital filter by feeding delayed versions of an input signal to the adaptive filter inputs.

Several applications for adaptive filters are presented in the video Adaptive noise cancellation can be used to reduce engine noise in ar aircraft communication system, achieve more accurate ECG readings or isolate an unborn child's heartbeat in an electrocardiograph Other applications include adaptive inverse control, echo cancellation statistical prediction, and antenna configuration. A taped segmen shows a computer simulation of an antenna learning to configure itsel to receive a desired signal with maximum gain while simultaneousl attenuating several directional noise sources or jamming signals.

The adaptive linear neuron, or Adaline, is covered next in the videc The Adaline is a simple artificial neuron which sums its weighte inputs and a variable threshold weight and feeds the resulting signa through a signum function in order to form the output. Widro shows how the Adaline can be trained with the LMS algorithm t give binary classifications to a set of input patterns as long as the patterns are linearly separable. The Adaline and the LMS algorithm are demonstrated with a hardware device called "Knobby" that is taught to distinguish between input patterns for the letters "T" and "J" as well as a vintage film segment that shows Widrow's lab at Stanford teaching an Adaline-augmented computer to perform speech recognition.

IX. Part II: Neural Networks

Part II of the video lecture starts with a short history of neural networks that includes Widrow's personal comments on the "death" of neural network research in the 1960's before the great renewal of interest in the 1980's. It is proceeded by an almost complete 1965 episode of the PBS series "Science in Action" dealing with Widrow and the research at his Stanford lab. It lasts approximately seventeen minutes and it covers Madaline, the inverted pendulum control problem, and weather prediction in the San Francisco Bay area.

Algorithms for training networks of Adalines and multilayer neural networks are then described. Widrow's original algorithm, called *Madaline I* (the name Madaline is derived from "Many Adalines"), for training single layer networks of Adalines is described, as well as the later revisions to the algorithm, Madaline II and Madaline III, which are used to train multilayer neural networks. Backpropagation is also described, with emphasis on its relationship to Madaline III and its use of the LMS algorithm at its heart.

The final part of lecture covers a method used by Widrow and his students for performing adaptive control of nonlinear systems with neural networks. The control method involves plant identification by a neural network and then backpropagation through the neural plant model to train a second neural network that acts as the controller. Two examples of nonlinear control are demonstrated in a video of computer simulations. The first example shows the controller learning to stabilize and center an inverted pendulum with first one and then two movable segments. The second example shows a neural network learning to back up a truck with one or two trailers into a loading dock.

Widrow concludes by emphasizing the main points of the lecture. He wants the viewer to understand the similarities and relationships of adaptive filters and neural networks as well as gain an understanding of Widrow's own work in the two fields.

The video is accompanied by copies of the overhead transparencies used, together with short abstracts of the two parts, and references for further reading. These are very helpful indeed.

Overall, Widrow sets out to present his own work in adaptive filtering and neural networks. In his presentation he includes both his recent research as well as his pioneering work, which made a significant contribution to the early development of these fields. The tutorial is excellent for people who wish to learn about the fields' history or who want an introduction to adaptive filtering and neural networks. No attempt is made for complete coverage of the current methods used in these two areas. It is only an introduction and even for further information on Widrow's own work one must rely on the references provided. The tape would be a good enhancement to an introductory course in adaptive filters and neural networks for both industrial practitioners and academics. It is a very well-done tape, a pleasure to watch.

The reviewers are with the Department of Electrical Engineering, University of Notre Dame, Notre Dame, IN 46556 USA.

IEEE Log Number 9404849.