TRACON Automation System (CTAS) (TRACON signifies "terminal radar approach control"). The invention reduces controllers' workloads and reduces fuel consumption by reducing the number of corrective clearances needed to achieve conformance with specified flow rates, without causing conflicts, while providing for more efficient distribution of spacing workload upstream and across air-traffic-control sectors.

Prerequisite to a meaningful summary of the invention are definitions of the terms "miles in trail" and "conflict probe":

- "Miles in trail" signifies a specified distance, in nautical miles, required to be maintained between airplanes.
- A conflict probe is a computer program that assists air-traffic controllers in maintaining safe distances between aircraft by predicting conflicts (essentially, close approaches with potential for collision) as long as 20 minutes in advance. The predictions are made by use of a combination of (1) information on the present state of the aircraft (horizontal positions, altitudes, and velocities) obtained by tracking; (2) information on the anticipated states of the aircraft obtained from flight plans; (3) information on atmospheric conditions; and (4) information on the aerodynamics and engine performance characterization of the airplanes.

In broad terms, the inventive method involves establishment of a spacing reference geometry (described below); prediction of locations of all aircraft of interest at the predicted time of intersection of the path of whichever of the aircraft is expected to first intersect the spacing reference geometry; and determination of the distances between aircraft on the basis of their predicted locations at that time. The design spacing reference geometry includes a collection of fixed waypoints (including locations of navaids, airway intersections, and predetermined latitude/longitude positions); airspace sector boundaries; arcs defined in reference to airports or other geographical locations; arbitrary lines in space; and combinations of line segments.

The software generates a display that includes the predicted locations and spacings of the aircraft of interest. The spacings can be indicated in any of a variety of formats — for example, alphanumerically on a list adjacent to a radar display showing flightpaths and spacing-reference-geometry features of a region of interest. When an alteration in flight characteristics (course, speed, and/or altitude) of one or more of the aircraft is proposed, the predicted locations and spacings are recalculated, thereby providing feedback as to conformance of the proposed alteration with the spacing requirement. In addition, a conflict probe is preferably used to determine whether the proposed alteration could cause a conflict.

By selection of spacing-calculation parameters, an air-traffic controller can specify whether the determination of spacing is one of rolling spacing, fixed spacing, absolute spacing distance, or relative spacing distance. It is possible to impose a "meet spacing" requirement, in response to which the software proposes, to the controller, changes of course, speed, and altitude of one or more of aircraft that would satisfy the spacing requirement. Aircraft may be selected by matching aircraft to input stream characteristics, as well as by directly identifying flights by controller input, and the selection process can be repeated at intervals. Spacing advisory data are preferably reported to other controllers responsible for monitoring each aircraft.

*This work was done by Steven Green and Heinz Erzberger of* **Ames Research Center**. *Further information is contained in a TSP (see page 1).*

*This invention has been patented by NASA (U.S. Patent No. 6,393,358). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14418.*

# Algorithm for Training a Recurrent Multilayer Perceptron

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An improved algorithm has been devised for training a recurrent multilayer perceptron (RMLP) for optimal performance in predicting the behavior of a complex, dynamic, and noisy system multiple time steps into the future. [An RMLP is a computational neural network with self-feedback and cross-talk (both delayed by one time step) among neurons in hidden layers]. Like other neural-network-training algorithms, this algorithm adjusts network biases and synaptic-connection weights according to a gradient-descent rule. The distinguishing feature of this algorithm is a combination of global feedback (the use of predictions as well as the current output value in computing the gradient at each time step) and recursiveness. The recursive aspect of the algorithm lies in the inclusion of the gradient of predictions at each time step with respect to the predictions at the preceding time step; this recursion enables the RMLP to learn the dynamics. It has been conjectured that carrying the recursion to even earlier time steps would enable the RMLP to represent a noisier, more-complex system.

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