Self-Optimizing Adaptive Antenna

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Introduction: Currently, in dynamically changing and highly uncertain electronic warfare (EW) environments it is not possible to design in advance EW hardware that can adapt in real-time to these complex environments autonomously. Particularly, the real-time adaptation of EW to rapid changes in hostile activity poses a technological challenge. The ability of combining reconfigurable hardware devices with optimization software capable of executing real-time autonomous reconfiguration opens up a new approach to many difficult EW problems. This paper describes a real-time implementation of Genetic Algorithms (GAs)[1] demonstrated in a specific hardware configuration.

Background: We assume that the structure of a reconfigurable hardware device or system can be changed in real-time through altering bit strings ("configuration bits"). GA theory indicates that an optimal solution can be found over a vast and diverse nonlinear space at reasonable computational costs. The GA treats the "configuration bits" of the reconfigurable hardware devices as a chromosome and optimizes the chromosome through evolutionary computation. If the GA fitness function is properly designed for the task, then the GA can autonomously find the best hardware configuration in terms of chromosomes (i.e., configuration bits). Since the fitness landscape unpredictably changes in EW environments, the sensors that detect the changes in the environment should be in the loop of a real-time adaptable EW system. In this study, a low cost V-dipole ("rabbit ear") antenna system was used to demonstrate this real-time approach in a readily available, inexpensive three degrees of freedom hardware.

Self-Optimizing Adaptive Antenna System Validation: The V-dipole antenna system consists of two elements that can rotate through two different axes (two degrees of freedom) on a rotating mount (one degree of freedom). In this demonstration we used the V-dipole antenna for television reception. Even though the antenna has a simple structure, finding the optimal position of the two telescoping elements for the best signal reception on a rotating mount is a complex task because the three degrees of freedom encompasses a very large set of possible position combinations. Also, the V-dipole antenna system must adapt to changes in the signal environment due to weather, terrain, and other interference. Figure 1 is a diagram of the real-time self-optimizing adaptive antenna system. The GA on the computer controls the positions of three servo motors through the servo controller in antenna positioning circuitry. The conventional GA, which typically requires off-line, non-real-time processing, was modified to provide a real-time computational capability. The computational flow chart of the modified GA is shown in Fig. 2. The

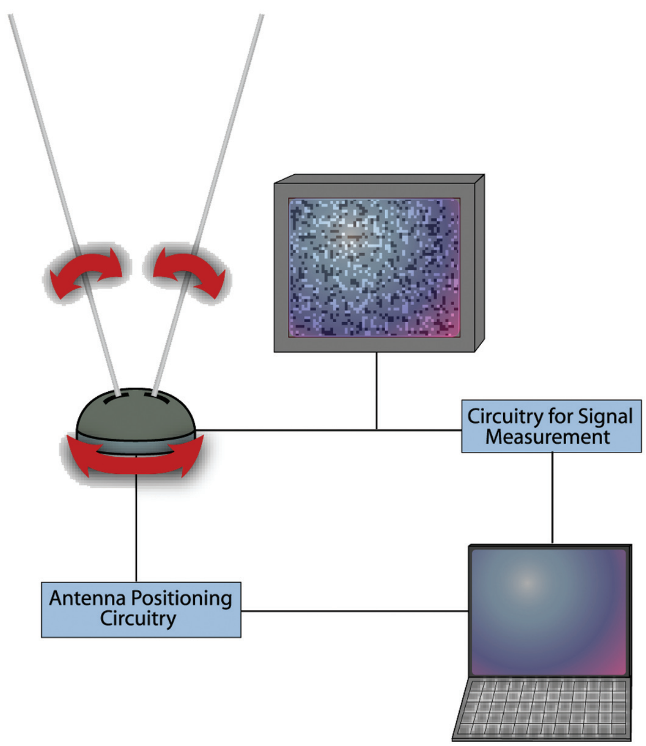

FIGURE 1
Self-optimizing adaptive antenna system.

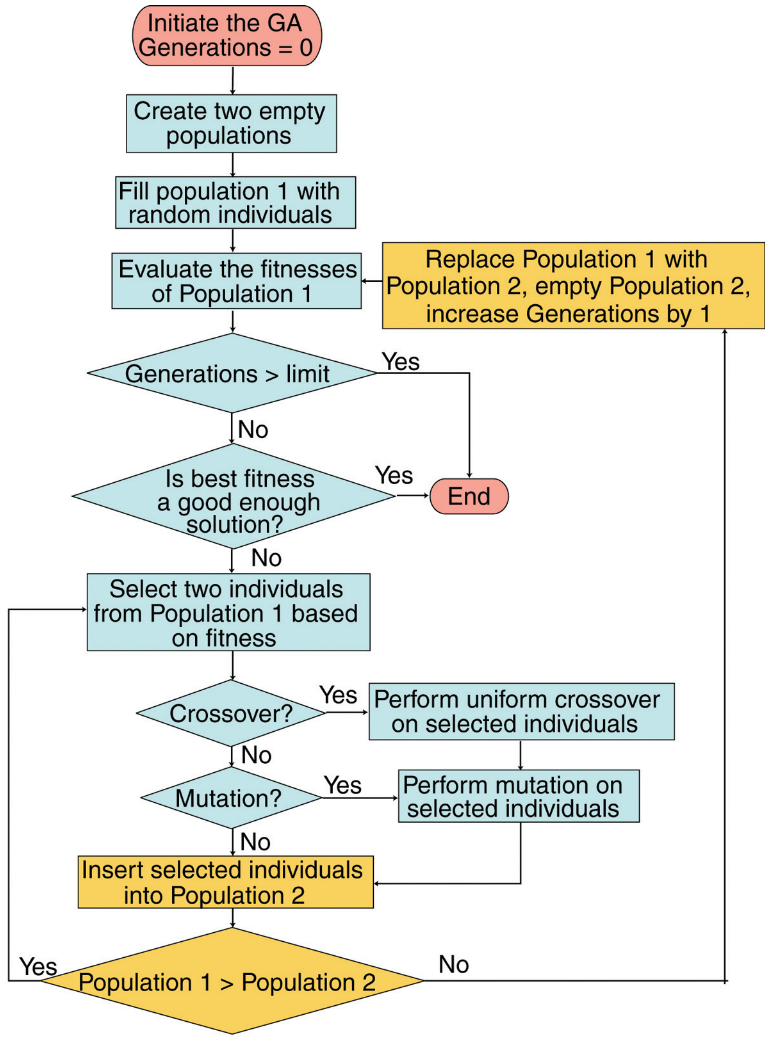

FIGURE 2
Flow chart of compact GA computational procedures.

modifications to the standard GA flow are shown in the yellow blocks. These modifications allowed the GA to be implemented in real time in the feedback circuit. The three angular positions of the servo are encoded in a chromosome of the GA population. The raw value of signal strength is measured as a fitness to estimate the performance of each position. This single value can incorporate all interference and noise in the signal. The raw signal value is digitized to provide discrete values to the new real-time GA algorithm. At the end of the computation, the system moves the elements to the best position as determined by the GA. In the validation experiment, as the television channels were changed, the GA adjusted the V-dipole antenna position to find optimal reception. The initial test hardware of the antenna system that validates this novel real-time solution is shown in Fig. 3.

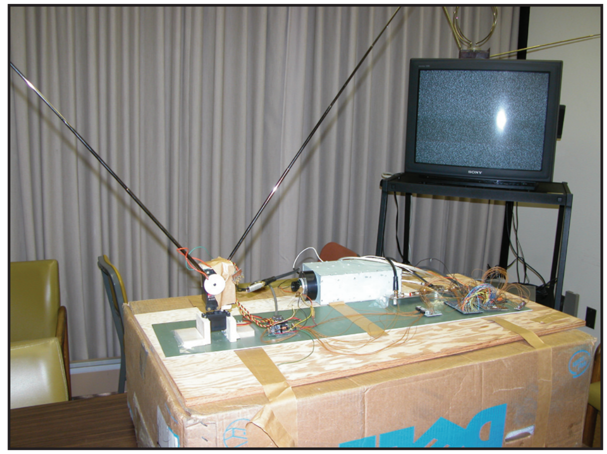

FIGURE 3
The initial test hardware of the self-optimizing antenna system.

Summary: An autonomous, real-time adaptive system combining GA and reconfigurable hardware was demonstrated using a low-cost, simple V-dipole antenna system. This system was controlled through a feedback loop that used evolutionary computation in real time to find antenna positioning that optimized received signal strength. Although this application was rudimentary, we project that chip-level real-time GA processing can be applied to more complex reconfigurable hardware such as field programmable gate arrays (FPGAs) to support more complex applications in autonomous and adaptable EW systems.

[Sponsored by ONR]

Reference

[1] D.E. Goldberg, *Genetic Algorithm in Search, Optimization & Machine Learning* (Addison-Wesley, 1989).

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