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ScienceDirect
Expert Systems with Applications 35 (2008) 1657–1667
Expert Systems with Applications
www.elsevier.com/locate/eswa

Genetic tracker with adaptive neuro-fuzzy inference system for multiple target tracking

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Abstract

In this paper, a genetic tracker with adaptive neuro-fuzzy inference system (GT-ANFIS) is presented for multiple target tracking (MTT). First, the data association problem, formulated as an *N*-dimensional assignment problem, is solved using the genetic algorithm (GA), and then the inaccuracies in the estimation are corrected by the adaptive neuro-fuzzy inference system (ANFIS). The performances of the GT-ANFIS, the joint probabilistic data association filter (JPDAF), the genetic tracker (GT), and the genetic tracker with neural network (GT-NN) are compared with each other for six different tracking scenarios. It was shown that the tracks estimated by using proposed GT-ANFIS agree better with the true tracks than the tracks predicted by the JPDAF, the GT, and the GT-NN.
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Keywords: Multiple target tracking; Data association; Genetic algorithm; Adaptive neuro-fuzzy inference system

1. Introduction

Target tracking is an essential requirement of surveillance systems, which consist of sensors and communication links, as well as computer subsystems to interpret the measurements of the sensors (Bar-Shalom & Li, 1995). The objective of the MTT is to form observations into tracks so that tracking filters can be applied to track the states of the individual targets. The accuracy of data association is critically important since mis-association of data to the targets will lead to tracking failure.

The problem of data association has been studied extensively in the literature (Angus et al., 1993; Bar-Shalom & Li, 1995; Carrier, Litva, Leung, & To, 1996; Chen & Hong, 1997; Chen & Huang, 2000; Fitzgerald, 1986; Fortmann, Bar-Shalom, & Scheffe, 1983; Hillis, 1997; Hossam et al., 1996; Leung, 1996; Pattipati, Deb, Bar-Shalom, & Washburn, 1992; Pattipati, Popp, & Kirubarajan, 2000; Poore, 1994; Poore & Robertson, 1997; Sengupta & Iltis, 1989; Singh & Balley, 1997; Turkmen & Guney, 2004a, 2004b; Turkmen, Guney, & Karaboga, 2004; Turkmen, Guney, & Karaboga, 2006; Wang, Litva, Lo, & Bosse, 1996). Some of the proposed solutions to this complex problem include the multiple hypothesis tracking, the joint probabilistic data association (JPDA), and the assignment (Bar-Shalom & Li, 1995; Fortmann et al., 1983; Pattipati et al., 1992; Pattipati et al., 2000; Poore, 1994; Poore & Robertson, 1997). These algorithms vary widely in their complexity and the resulting tracking performance. The multiple hypothesis tracking forms a number of association hypotheses from several scans and it delays the decision to a later time when more information becomes available. However, the exhaustive search over all possible hypotheses can be very expensive. Because of this difficulty, recursive algorithms having smaller computational requirements were developed. The JPDAF (Bar-Shalom & Li, 1995) is one of these recursive algorithms, commonly used for the MTT. It works without any prior information about the targets and clutters. There are two major steps in the JPDAF: data association and filtering. Data association is a process of assigning a new measurement to a target in order to perform the filtering operation. The track

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0957-4174/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2007.08.065

filtering is a sequential computational process used to estimate a target state vector and to make a correction to the estimated state upon receiving a new measurement. The central feature of the JPDAF is the determination of association probabilities. The association probabilities of every observation with each existing track file are computed by using the covariances of the respective state vectors obtained from Kalman filtering (Kalman, 1960). Each track file is updated, via Kalman filtering, by an input equal to a weighted average of all observations. The computational complexity for the joint probabilities increases exponentially as the number of targets increases. To reduce this computational complexity significantly, the cheap JPDAF (CJPDAF) was presented by Fitzgerald(1986). The weighted average state update of the CJPDAF is the same as that of the JPDAF, except that in the CJPDAF the approximate probabilities are used. In the CJPDAF, each track file is also updated via Kalman filtering. In either dense target or cluttered environment the tracking performance of the CJPDAF also decreases. In our previous work (Turkmen & Guney, 2004a), the CJPDAF with the ANFIS state filter was proposed for tracking multiple targets in the presence of low and high cluttered environments. In Turkmen and Guney (2004a), the state update step of the CJPDAF was realized with the use of the ANFIS state filter instead of Kalman filter. In Turkmen and Guney (2004b) and Turkmen et al. (2004), we also successfully introduced artificial neural network and tabu search algorithm for MTT.

Data association using a multidimensional assignment algorithm, where the measurements in the last N scans are associated with the list of tracks (N lists-N-dimensional association, denoted as N-D), has been shown to be a practical and feasible alternative to the multiple hypothesis tracking without the limitation of exhaustive enumeration. In the multidimensional assignment formulation of data association, the association between the lists of measurements and the list of tracks is formulated as a global discrete optimization problem, subject to certain constraints, where the objective is to minimize the overall cost of association. The N-D assignment problem for associating data from three or more scans of measurements ($N \geqslant 3$) is known to be NP-hard. It is well known that solving such a constrained optimization problem is intractable. The GA (Davis, 1991; Holland, 1975) can be used successfully to solve NP-hard problems. It is well known that the search technique, the GA, is a parallel, robust, and probabilistic search technique that is simple and easily implemented without gradient calculation, compared to the conventional gradient-based search procedure. Most important of all, the GA also provides a mechanism for global search that is not easily trapped in local optima. Several methods (Angus et al., 1993; Carrier et al., 1996; Chen & Hong, 1997; Hillis, 1997) based on the GA have been proposed for target tracking. In Angus et al. (1993) and Carrier et al. (1996), the GA was used for data association within single scan. Hillis (1997) has presented a method to recast the multiscan assignment problem as a scheduling problem, in which the GA searches for an ordering of reports that produces good assignments. In order to solve multidimensional assignment problem, a dynamic fuzzy mutation GA has been proposed in Chen and Hong (1997).

The problem in the literature is that a method that is as simple as possible for target tracking should be obtained, but the tracks estimated by using the method must be in good agreement with the true tracks. In this paper, a method based on the ANFIS (Jang, 1993; Jang, Sun, & Mizutani, 1997) and GA for efficiently solving this problem is presented. The data association problem is first formulated as an N-dimensional assignment problem and then solved using the GA. Next, the ANFIS is incorporated into the GT to reduce the estimation error of the GT. In the GT, the target states are updated by using Kalman filter. The Kalman filtering is effective for simple scenarios such as in a clutterless environment or a single sensor tracking a single target. However, under dense target environment, extraneous sensor reports may be incorrectly used by the Kalman filter for track update, thus resulting in degraded performance, possibly loss of track may occur. In Turkmen et al. (2006), we proposed GT-NN method in which the inaccuracies in the estimation of Kalman filter are corrected by using artificial neural network (ANN). In order to further improve the state estimation of the Kalman filter, in this paper ANFIS is incorporated to the GT instead of the ANN used in Turkmen et al. (2006).

The fuzzy inference system (FIS) forms a useful computing framework based on the concepts of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning (Jang et al., 1997). The ANFIS is a FIS implemented in the framework of an adaptive fuzzy neural network, and is a very powerful approach for building complex and nonlinear relationship between a set of input and output data. It combines the explicit knowledge representation of FIS with the learning power of neural networks to achieve a desired performance. Fast and accurate learning, excellent explanation facilities in the form of semantically meaningful fuzzy rules, the ability to accommodate both data and existing expert knowledge about the problem, and good generalization capability features have made neuro-fuzzy systems popular in recent years (Brown & Haris, 1994; Constantin, 1995; Jang, 1993; Jang et al., 1997; Kim & Kasabov, 1999; Lin & Lee, 1996). Because of these attractive features, the ANFIS in this paper is used to improve the tracking accuracy of the GT.

In previous works (Akdagli & Guney, 2000; Guney & Sarikaya, 2004a, 2004b, 2004c, 2004d, 2006a, 2006b; Karaboga, Guney, Karaboga, & Kaplan, 1997), we proposed ANFIS (Guney & Sarikaya, 2004a, 2004b, 2004c, 2004d, 2006a, 2006b) and GA (Akdagli & Guney, 2000; Karaboga et al., 1997) for calculating accurately the various parameters of the triangular, rectangular and circular microstrip antennas. In the following sections, the JPDAF, the GA, the ANFIS, and the GT-ANFIS proposed in this paper are described briefly, and the simulation studies are then presented.

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