ELSEVIER

Chinese Astronomy and Astrophysics 42 (2018) 141–154

CHINESE ASTRONOMY AND ASTROPHYSICS

Estimation of Distribution Algorithm for Initial Orbit Determination of Too-short-arc Based on Kernel Density Estimation† ⋆

WANG Xin[1,2] LI Xin-ran[1,2,3]

[1] *Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008*

[2] *Key Laboratory of Space Object and Debris Observation, Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008*

[3] *University of Science and Technology of China, Hefei 230026*

Abstract A new approach of the initial orbit determination for too-short-arc with angular measurements is implemented by building the probabilistic model in the solution space with the estimation of distribution algorithm. Without any assumption about distribution, the non-parametric kernel density estimation is employed in the model building. The method, unlike other evolutionary algorithms, such as the genetic algorithm and particle swarm optimization, considers the fitness as well as the characteristics of the solution space. Numerical experiments with real observations indicate that without any constraints, the proposed technique has a good performance for the observations of usual accuracy.

Key words space vehicles, celestial mechanics: orbit determination, methods: numerical, methods: statistical

1. INTRODUCTION

The main purpose of cataloging space targets is to own the exact orbits of in-service satellites and space debris, and thus to predict their locations and support space activities. To obtain accurate orbits, the sufficiently long orbital arcs and enough number of observational data are necessary. However, with the increasing number of space targets, the target-oriented tracking observations can not meet the practical requirements. In recent years, the observation of space targets has gradually changed to the space-oriented mode. At present, more than

† Supported by National Natural Science Foundation (11373072).

Received 2016–01–27; revised version 2016-02-29

⋆ A translation of *Acta Astron. Sin.* Vol. 57, No. 6, pp. 673–682, 2016

△ wangxin@pmo.ac.cn

doi:10.1016/j.chinastron.2018.01.009

80% of the optical angle measurements of low-orbit space targets in China are obtained in this way, thus the space-oriented mode is the main data source of China's catalog system. Nevertheless, this observation approach increases the amount of observations as well as brings new problems. For each target, the observing arc is so short, often of only tens of seconds or even just over a dozen, that is not enough to determine an accurate orbit. Therefore it is necessary to combine many short arcs of an orbit together to achieve an accurate orbit determination. Consequently, the researches on how to efficiently obtain the information from very short arcs and how to improve the correlating efficiency become more and more important. Even in the tracking mode, it is still very helpful to improve the efficiency of observation if an effective orbit can be obtained through short arcs[1].

The short-arc orbit determination is a classic problem, with the main difficulty lying in the intrinsic illness of the problem. The shorter the arc, the more prominent the illness[2]. The Genetic Algorithm (GA) was introduced to solve the problem of space-based short-arc orbit determination[3]. The same method was applied to studying the ground-based short-arc orbit determination in Reference [4], but with a GA operator different from [3]. The GA method overcomes the difficulties of not being able to achieve reasonable solutions in classical methods, but the deviation and dispersion of the solution are still quite large. A new algorithm using completely different optimization variables, fitness function and GA operator, was proposed in References [5-6]. Under certain constraints, the deviation and dispersion of the solution are reduced, which satisfies the requirement of subsequent applications. In Reference [7], a method using the Particle Swarm Optimization (PSO) was studied and similar results as those in References [5-6] were obtained. It is noteworthy that the Evolutionary Algorithm (EA) has been applied to all the aforementioned studies. For the calculating procedures different from the classic methods in the EA, Reference [8] however proposed a general data processing strategy, which achieved the orbit determination with a very high collapse point through the robust estimation method. All this has established a framework of solving the problem of too-short-arc orbit determination via the EA method, but for a specific job in practice, the methods, operators, parameters and constraints should be carefully chosen. For the cataloging dealing with large amount of targets, it is obviously not the best choice to set too many constraints and parameters.

In this paper, we explore this problem from another angle. Our experiences in the preliminary orbit determination suggest that the minimal residual root mean square (RMS) cannot be regarded as the only criterion for the quality of the preliminary orbit determination. Within the precision range, multiple solutions can be attained for the short arc orbit determination, and the RMSs of these solutions are very close to each other. And even worse, the solution with the minimal RMS may be not the really optimal solution[9]. All the aforementioned studies focus on searching for the single solution with the minimal RMS, while neglect an overall checking on all the possible solutions. In this paper, we will introduce the Estimation of Distribution Algorithm (EDA)[10] to find the best solution from