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Genetic Algorithm for Initial Orbit Determination with Too Short Arc (Continued)† ⋆

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Abstract When the genetic algorithm is used to solve the problem of too-short-arc (TSA) orbit determination, due to the difference of computing process between the genetic algorithm and the classical method, the original method for outlier deletion is no longer applicable. In the genetic algorithm, the robust estimation is realized by introducing different loss functions for the fitness function, then the outlier problem of the TSA orbit determination is solved. Compared with the classical method, the genetic algorithm is greatly simplified by introducing in different loss functions. Through the comparison on the calculations of multiple loss functions, it is found that the least median square (LMS) estimation and least trimmed square (LTS) estimation can greatly improve the robustness of the TSA orbit determination, and have a high breakdown point.

Key words space vehicles—celestial mechanics—methods: numerical, statistical

1. INTRODUCTION

In recent years the survey observations of space objects have collected a large number of data, but different from the traditional tracking observations, the arc segments acquired by the survey observations are all very short, generally several ten seconds. In order to employ

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effectively these data, the too-short-arc (TSA) orbit determination has received more and more attention[1].

As the problem of short-arc orbit determination is basically ill-conditioned, the ill-condition of TSA is even distinct, the traditional method almost can not obtain a reasonable result. Reference [2] applied the genetic algorithm to the problem of TSA orbit determination, and adopted the genetic algorithm to convert the problem of orbit determination into the problem of optimization, so that the solution of linear algebraic equations is avoided, and some defects of the traditional method are overcome. Different from the classical optimization algorithm, the genetic algorithm has no special requirement on the initial values, it can hardly fall into local extreme values, hence it is an effective method to solve the problem of TSA orbit determination. Reference [3] adopted the completely different variables and genetic operators, and gave as well a concrete method for the TSA orbit determination by using a kind of genetic algorithm.

The studies mentioned above have given the method of orbit determination, but have not concerned about the problem of outlier deletion. In the preliminary orbit determination of actually-observed data, the problem of outliers is unavoidable, a small number of outliers in the observed data may produce a very large effect on the calculated result, even a destructive effect[4]. The common method to deal with the outliers is to delete the observed data with larger deviations according to the 3σ criterion in the iterative process, and let them do not join in the orbit calculation, so that to obtain a reliable result after convergence. Different from the classical algorithm, the genetic algorithm can not adopt such a process to delete outliers, at the same time, the judgement and deletion of outliers should be performed gradually in the calculating process, and the deletion itself will influence on the result of orbit calculation, so the outlier deletion is not easy.

Another way to deal with the outliers is to adopt the robust estimation method. Reference [5] adopted the M-estimate in the orbit calculation, but this method is relatively complex, especially, it needs reliable initial values, and the reliable initial value itself is a difficult problem, under this limitation the breakdown point of this method is not high enough. Besides, this method has introduced in extra parameters, and there has been not yet a feasible method to determine these parameters. In Reference [5], these parameters were given according to the statistical characteristics of historical data, however this method is not adaptable for the TSA data, because of the fewer dada.

References [6,7] adopted the Least Absolute Deviation (LAD) estimation, it does not need extra parameters, so the problem of parameter determination is avoided, but the linear programming method is adopted in the derivation of solution, this method is completely different from the general calculation process, it suits only the specific case of LAD.

In the practice of preliminary orbit determination, the outlier deletion is an unavoidable sector. On the basis of Reference [3], this paper discussed the treatment of outliers in the genetic algorithm, according to the characteristics of the genetic algorithm, this paper