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Book Review

Publishers are invited to send two copies of new books for review to Dr. I. Michael Ross, Code: AA/Ro, Department of Aeronautics and Astronautics, U.S. Naval Postgraduate School, 699 Dyer Road, Monterey, CA 93943.

Celestial Dynamics at High Eccentricities. Advances in Astronomy and Astrophysics Vol. 3

Victor A. Brumberg and Eugene V. Brumberg, Gordon and Breach Science Publishers, 1999, 220 pp., $95.00, ISBN 90-5699-212-0

The text is primarily about analytical and semianalytical techniques for use with satellites, asteroids, and comets. It is 212 pages long, and it's broken into 6 chapters. The text is quite readable and there are numerous detailed derivations and formulas.

We have seen substantial interest in numerical methods for orbit determination over the last few years.[1,2] However, this assumes that the numerical techniques will satisfy all mission planning requirements. Bromberg clearly states the role that analytical techniques play as an input for mission planning and analysis. The authors suggest numerous reasons why we need analytical and semi-analytical techniques, from semi-analytical theories of the Moon by Chapront and Chapront Touzé,[3] to the well-known analytical techniques for general orbit determination. In particular, the authors discuss why these techniques are needed to examine highly eccentric orbits. Their basic premise is to replace the true, mean, and eccentric anomalies with the elliptic anomaly. This is necessary to model the motion of highly eccentric orbits.

The first chapter begins with a detailed background of the elliptic anomaly, nome functions, recurrence relations, and other material needed to support the rest of the text. The eccentric anomaly in the two-body problem is presented to introduce the basic concepts. The authors describe the solution of the elliptic two-body problem in closed form. Because of the importance of elliptic functions to this solution, there is a detailed treatment of trigonometric expansions and the elliptic anomaly. They expand the discussion to introduce the eccentric anomaly in perturbed motion. Finally, the authors include a discussion of parabolic and hyperbolic two-body motion using Jacobi elliptic functions.

Chapter 2 discusses the elliptic anomaly in perturbed motion. The authors use Keperlian elements, but replace eccentricity with the nome (q). The Lagrange VOP equations are the starting point, and this section provides the basic foundation for the three cases examined: satellites, asteroids, and comets. They explore operator expansions of elliptic motion functions. Many references to Mathematica (Wolfram 1996) options are given. In some cases, recurrence relations for Hansen coefficients are presented for results obtained from FORTRAN-90 and Mathematica. The chapter closes with techniques used to integrate the Lagrange equations and a description of the elliptic anomaly as a canonical variable.

The third chapter covers the theory for highly eccentric satellite orbits. Beginning with disturbing functions and expansions, they also include partial derivatives resulting from the nonsphericity of the primary body. The disturbing function and derivatives are given for the third-body attraction. They then separate the effects into secular and first-order periodic values so that they can list the main perturbing terms for satellite motion.

Chapter 4 introduces the theory of motion for asteroids whose orbits are nonintersecting. That is, they do not collide with the primary body. Again, the expansion of the third-body function is given, along with partial derivatives, the separation of secular and periodic terms, and the main perturbing terms.

Next, the authors explore intersecting orbits. They remark that one needs expressions at all points except the actual collision point. They develop a disturbing function, give partial derivatives, and they conclude by examining the linear perturbations of the osculating elements.

The final chapter presents a series of computational formulas. While these are not given in algorithm form per se, they are designed for programming on a computer, or within Mathematica. To reduce space, and to allow a more general approach, actual source code is not provided. This is sure to please some, and to frustrate others—probably equally! The topical areas include: hypergeometric functions, Hansen coefficients, Hansen coefficient derivatives, the Kaula inclination functions,[4] the derivatives of the Kaula inclination functions, generalized inclination functions, symbolic Hansen coefficients, symbolic hypergeometric functions, the Jacobi nome, the modulus of the Jacobi elliptic functions, complete elliptic integrals, standard expansions of Jacobi elliptic functions, nome functions, symbolic nome functions, and some checking relationships.

This is an important reference because it addresses the rationale and underlying principles that govern the dynamics and characteristics of highly eccentric orbits. The analytical and semi-analytical principles apply to other disciplines as well. There is an excellent theoretical basis and collection of material relating to highly eccentric orbits. The graphs and supporting examples are interspersed throughout the text, and the index and references are modest. The numerous checks of the

equations using Mathematica are reassuring for a text with so many equations. Finally, the overall style is somewhat casual and it portrays a relatively enjoyable reading experience.

References

[1]Boers, J., Coffey, S., Barnds, W. J., Johns, D., Davis, M., and Seago, J., "Accuracy Assessment of the Naval Space Command Special Perturbations Cataloging System," *Advances in the Astronautical Sciences, Spaceflight Mechanics*, edited by C. A. Kluever, Vol. 15, Univelt, San Diego, CA, 2000, pp. 1291–1304.

[2]Coffey, S. L., Neal, H. L., Visel, C. L., and Conolly, P., "Demonstration of a Special-Perturbations-Based Catalog in the Naval Space Command System," *Advances in the Astronautical Sciences, Spaceflight Mechanics*, edited by J. W. Middour, Vol. 99, Univelt, San Diego, CA, 1998, pp. 227–248.

[3]Chapront, J., and Chapront-Touzé, M., "Lunar Motion: Theory and Observations," *Celestial Mechanics*, Vol. 66, 1997, pp. 31–38.

[4]Kaula, W. M., *Theory of Satellite Geodesy*, Blaisdell Publishing Co., Waltham, MA, 1966.

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