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Comparison between various existing techniques for computation of geopotential coefficients

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Recent advancements in the gravity field observation (namely surface, airborne, and gravity satellite field observations) have resulted in vast amount of high quality gravity data, and as such, computation of gravity field models in terms of spherical or ellipsoidal coefficients to high degree and order has become a challenge. Gravitational potential expansion to degree 2160 by Pavlis et al. 2004 (reported in proceeding of GGSM 2004) and several recent contributions by Reigber et al. can be regarded as examples of recent activities towards high-resolution gravity field modeling based on recent gravity missions. One of the main problems involved in the high degree and order geopotential expansions is huge amount of input data as well as tremendous number of unknowns involved in the computations. Therefore, at the geodesy division of University of Tehran, as one of the groups trying to be active in gravity field modeling, it has always been questioned how we could compete with our colleagues in the production of new gravity field models, yet by having by far limited computational hardware assets. Having this question in mind following computational techniques are compared and their capabilities for the production of geopotential coefficients based on commercial PC are studied: 1. Least squares method based on Cholesky decomposition, QR decomposition, and Singular Value Decomposition (SVD), 2. Iterative method based on steepest descent and conjugate gradient 3. Fast Fourier Transform (FFT) method. According to the test computations, if the number of observations with respect to the number of unknown parameters become large, the Cholesky decomposition is faster than QR decomposition and SVD, but for ill-conditioned systems, the QR decomposition or the SVD will provide more accurate results as compared with Cholesky decomposition. Least squares method can also be made faster by introducing parallel processing.

With iterative methods (such as steepest descent and conjugate gradient) there is no need to build the normal equations explicitly used and therefore they do not involve matrix inversion. As a result, iterative methods are very fast and need smaller computer memory for the computations, but they need the initial value at the starting level of the iteration and besides those methods do not give actual covariance matrix but only an approximation of it.

In FFT method, thanks to orthogonality of spherical harmonics, the method is very stable and also fast. However, this method requires the potential values on the surface of reference sphere or reference ellipsoid, which in term requires downward continuation of the boundary observations. The other issues of importance in this respect are: (i) The need for more accuracy in the potential values in the longitude direction on the surface of reference sphere or ellipsoid. (ii) The impact of sampling interval and importance of consideration of Nyquist frequency in the sampling intervals.

As final conclusion we should say that FFT method, when the computational facilities are limited could be considered as the optimum computational solution for gravity field modeling such as University of Tehran.