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From GSM positioning to the identification of multiple spherical magma sources using GPS data: the TOPINV algorithm and software

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Inversion of spherical (Mogi) multiple magma sources from surface deformation data is a very difficult task because it corresponds to the inversion of a redundant, highly non-linear system of equations, and is usually faced in the basis of sampling techniques (up to 10^4-10^6 Monte Carlo-based samples). An alternative, quasi-deterministic topological inversion based on the principles of beacon or GSM positioning has been proposed to solve this problem: the location of a point is determined from the common surface (intersection of geometric loci) of the areas covered by a beacon/GSM cell, using simple forward computations only.

Our approach is exemplified in the solution of a system of n equations and two unknowns (x,y).

First, a 2D grid G is defined with all possible locations of (x,y) approximated by individual points.

Second, for each measurement/observation i a simple inequality is formed; this inequality defines that the (forward) predicted value for a point of the grid minus the observed value is in absolute value smaller than a factor $k$times the standard error of the measurement. Grid G is "scanned" with this inequality and subset S_i of its points which satisfy this inequality (Boolean operation) is defined. The process is repeated for all n observations and n subsets S_i are defined.

Third, the common section S of these subsets S_i, if there exists, contains the solution of the system, and an estimate of this solution is derived as the center of gravity of S.

Fourth, the solution is optimized repeating this process for various values of k, until a minimal value of S and a minimum variance of the solution is obtained.

This approach can be generalized for n unknown variables, leading to a grid G in R^n space, $R^4$for a single Mogi source and R^8 for a double one. Techniques to focus on unique, statistically significant solutions (especially minimal trade-off between depth and volume of modeled sources) and to calculations limited to less than 10^9 gridpoints are proposed and are incorporated in the TOPINV software. The overall method and the software were tested in an accuracy-oriented approach. Magma sources were assumed ("real values"), synthetic GPS measurements were produced and through blind TOPINV-inversion, estimates of the sources were computed and compared with the "real" values.

TOPINV permits forward and inverse calculations for one or two Mogi sources using GPS data and is freely available. Modifications to include other types of observations are possible.