Inversion of thermal layering data through numerical modeling assisted by genetic algorithms

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Various experiments dedicated to the insitu investigation of the thermal properties of subsurface materials are under development (HP^3, EXTASE) or in flight toward their destination (MUPUS on Rosetta).

All share a common configuration and working principle with long, thin probes equipped with sensors and heaters, and placed in the material to heat it up and record the heating and cooling phases.

Various theories allow the correlation of these temperature curves with thermal properties. Unfortunately, the realization and practical implementation of the experiments introduce a high number of additional parameters and errors that make the use of analytical means for inversion uneffective.

To overcome these problems, another approach has been implemented: the process done by the probes is simulated with an engineering thermal numerical model (ESA-TAN code) and the results are compared with the experiment. The error of the fit is then evaluated with an ad-hoc function.

The entire process from the guess of the parameter set to determination of the error is very fast and does not require excessive manpower.

Due to the high number of parameters, the high non linearity of their interconnections, and the absence of previous knowledge on the material (e.g. comet surface), it is necessary to have a way to select, in the least time, the optimum set of values which fit the experimental data.

Genetic Algorithms (GA) are the method we selected. They are applied to the numer-

ical modeling to explore the parametric space and search for the optimal combination of values that minimize the fitting error.

A GA module is devoted to the creation of model sets that are run and fit against the experiment by a simulation module containing the thermal model.

Starting from a pseudo-random set of parameters, the GA module generates a set of initial models that are passed to the simulation module. As a result the corresponding error is passed back to the GA, where Arithmetic Crossover is used to mix properties of different models and Tournament Selection is then used to generate the successive set of models.

In this paper, the results from terrestrial experiments are used to verify the procedure and prepare the method for future space-applied uses.