

techniques involve mathematical transformations such as principal component analysis, kernel principal component analysis, discrete cosine transformation, adaptive spatial zonation, and coarsening of the reservoir model. However, the rationale for reparametrization, namely for the choice of model complexity and size of parameter space (*i.e.* degree of compression) is based on prior knowledge (*i.e.* optimal compression which can reproduce the original parameter estimates with insignificant error). As a result, these parameterization techniques are relatively ill-equipped for estimation of the values of reservoir parameters so that future production predictions are reliable. Thus, improved history matching methods are needed for improving the prediction capability of reservoir models.

SUMMARY

[0007] The Embodiments of the present disclosure presents invention provide methods and apparatus for improved estimation of reservoir performance, for example, such as prediction of future oil or gas production rates and pressures. As described herein, these methods and apparatus use cross-validation to determine an optimum number of parameters and numerical values of parameters upon which to base a production forecasting model.

[0007a] For example, A first aspect of the present disclosure describes invention provides a method of determining a geological model which may include comprising the acts of identifying an array of parameter sets, wherein each parameter set is of a unique size and contains values of geological parameters estimated from historical production data associated with a target geological region. ~~Additionally, such an example method may include~~ determining a fitting error between a first set of the historical production data and modeled production data, wherein the modeled production data is obtained via through execution of a simulation model based on each parameter set of the array, determining a validation error between a second set of the historical production data and extrapolated production data for each parameter set of the array, wherein the extrapolated production data is obtained based on the modeled production data for the respective parameter set of the array, ~~and~~ determining a combined error for each parameter set of the array based on the fitting error and

the validation error. ~~In addition, the example method may include~~and
identifying an optimal parameter set size for modeling the target geological
region, wherein the

optimal parameter set size is determined in reference to a minimum combined error of the combined errors determined for each parameter set of the array.

5 [0007b] A second aspect of the present invention provides an apparatus for determining a geological model, comprising:
one or more processors, and
a machine readable storage device comprising instructions that when executed
by the one or more processors, perform operations comprising,
identifying an array of parameter sets, wherein each parameter set is of a unique
10 size and contains values of geological parameters estimated from
historical production data associated with a target geological region;
determining a fitting error between a first set of the historical production data
and modeled production data, wherein the modeled production data is
obtained through execution of a simulation model based on each
15 parameter set of the array;
determining a validation error between a second set of the historical production
data and extrapolated production data for each parameter set of the array,
wherein the extrapolated production data is obtained based on the
modeled production data for the respective parameter set of the array;
20 determining a combined error for each parameter set of the array based on the
fitting error and the validation error; and
identifying an optimal parameter set size for modeling the target geological
region, wherein the optimal parameter set size is determined in reference
to a minimum combined error of the combined errors determined for
25 each parameter set of the array.

[0007c] A third aspect of the present invention provides a non-transitory
computer-readable medium comprising instructions that, when executed by a
computer, cause the computer to perform operations comprising:
30 identifying an array of parameter sets, wherein each parameter set is of a unique
size and contains values of geological parameters estimated from
historical production data associated with a target geological region;

determining a fitting error between a first set of the historical production data and modeled production data, wherein the modeled production data is obtained through execution of a simulation model based on each parameter set of the array;
5 determining a validation error between a second set of the historical production data and extrapolated production data for each parameter set of the array, wherein the extrapolated production data is obtained based on the modeled production data for the respective parameter set of the array;
determining a combined error for each parameter set of the array based on the
10 fitting error and the validation error; and
identifying an optimal parameter set size for modeling the target geological region, wherein the optimal parameter set size is determined in reference to a minimum combined error of the combined errors determined for each parameter set of the array.

15 [0008] The above examples of the present disclosure present merely examples that will be further described and expanded in the detailed description and in view of the Figures presented below.

20 BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a graphical representation of a modeled production data vector over time;

[0010] FIG. 2 is a similar graphical representation of a modeled production data vector over time;

25 [0011] FIG. 3 is a graphical representation displaying a combined error in relation to fitting error and validation error;

[0012] FIG. 4 is a block diagram illustrating a computer device for production data estimation;

[0013] FIG. 5 is a block diagram illustrating a module for production data
30 estimation;

[0014] FIG. 6 is a flow diagram illustrating an example method of production data estimation in an example of the disclosure;

[0015] FIG. 7 is a block diagram illustrating an example grouping of electrical modules for production data estimation; and

[0016] FIG. 8 is a block diagram illustrating a machine in the example form of a computer system, within which a set or sequence of instructions for causing the machine to perform any one of the methodologies discussed herein may be executed, according to an example embodiment.

DETAILED DESCRIPTION

[0017] The present disclosure presents methods, apparatuses, and systems for estimating parameter values of a target geological region, which may contain one or more underground reservoirs, based on cross-validation techniques in order to improve forecast capability of a simulation model based on estimated parameter values of a target geological region. For example, the present disclosure proposes a method for identifying an optimum number and numerical