

Quick Setup

Koko Simulator for Eclipse Users

By Focus Simulation Inc.

Step 1. Run an Eclipse deck as it is

Users can launch the Koko simulator via the Koko client, a graphical user interface. The Koko simulator runs an Eclipse deck as it is. Acceptable Eclipse keywords and new Koko simulator keywords are summarized at the end of this document.

The Koko simulator will place the output files in the same directory as that of input file. The output files have the same name as the input file, but with different file type. For example, given an input file of case1.data, we will have the following output files: case1.lst, case1.dbg, case1.sim, case1.sum, case1.ohist, case1.nnc, case1.orfttxt, case1.rst6. We may need additional input files such as case1.obs (an Eclipse observation file), case1.nncgrid (a file contains non-standard connections), case1.rst5 (a restart input file), case1.rfttxt (RFT pressure data).

Occasionally, the automatic memory allocation of Koko may not be sufficient. Koko will output the required memory in case1.lst. The following line can be added in the RUNSPEC Section of the data set to manually allocate the array dimension:

```
ARRAYDIMENSION NRT NIT NCT ND /
```

NRT is the dimension for the real array, NIT for the integer array, NCT for the character array, and ND for the number of data to be optimized. If automatic allocation is to be used for certain dimensions, then substitute the dimension with # such as follows:

```
ARRAYDIMENSION # NIT NCT # /
```

Step 2. Conduct approximation runs of the original Eclipse deck

Add the following lines in the RUNSPEC Section of the original Eclipse deck. Then launch Koko.

```
AUTOCOARSEN 0.4 0.4 1.0 IMPLICIT 1 /  
NORMSATENDPT /
```

The first line states that the coarsening will reduce the model size by 0.4 in both the x and y dimensions. The coarsened grids will use an implicit formulation and it will have only one level of coarsening. The actual model size of this run will be approximately 0.4*0.4 of the original model size.

The second line- NORMSATENDPT is required for a coarsened model. It is a good practice to use a single rock region, although this is not a requirement. With a single rock region, users can still adjust saturation end points and relative permeability at these end points to mimic multiple rock regions.

If the results of the coarsened model deviate significantly from those of the original model, it implies the coarsened model is inadequate. In this respect, Koko is useful for *studying grid sensitivity*.

Step 3. Conduct an optimization run of the coarsened Eclipse deck

3a) Add the following lines in the RUNSPEC Section of the Eclipse deck.

```
ANALYTICALDERIV /  
CHAOTICSEARCH 40 1 40 2.0 /  
OPTMMAXITN 5 /  
OBSERVATIONFILE case1.obs /  
RFTTXTFILE /
```

The first line states that the analytical derivative is to be used. When the analytical derivative is used, the types of properties that can be optimized will be limited. Currently, these properties are porosity, permeability, pore volume, transmissibility, initial gas/oil contact, initial water/oil contact, initial solution gas oil ratio, skin factor, and PI multiplier.

The second line states that a chaotic search is used with a maximum of 40 iterations. The random seed is 1. The number of iterations per cycle is 10. (The search radius will be halved every 10 iterations.) The initial temperature (not reservoir temperature) for chaotic search is 2.0.

The third line states a gradient search with a maximum number of 5 iterations will immediately follow the chaotic search. The minimum located by the chaotic search will be used as the initial guess for the gradient search.

The fourth line states that the field data can be found in case1.obs which is in Eclipse observation file format. The data could alternatively be entered via WCONHIST keyword in the SCHEDULE Section.

The last line states that RFT pressure data that are stored in a .rfttxt file.

3b) Add the Optimization Parameter Section.

The Optimization Parameter section is after the RUNSPEC Section.

In principle, any real number can be optimized. However, if analytical derivative is activated, only properties that are eligible for analytical derivative can be included in the gradient search. An example of the Optimization Parameter Section is shown next.

```
-----
-- An Example Optimization Parameter Section -
-----
--
-- First Specify the Parameters
-- Parameter 1 will have an initial guess
-- of 0.1, a minimum value of 0.01, a maximum
```

```
-- value of 0.95, and a perturbation size of 0.01.
-- (Perturbation size is used to calculate the
-- sensitivity coefficients via a numerical
-- derivative. If analytical derivative
-- is activated, the value is redundant.)
-- Parameter 2 and Parameter 3
-- are similarly defined.
```

```
PAR#1 0.1 0.01 0.95 0.01 /
PAR#2 1.0 -10.0 10.0 0.01 /
PAR#3 1.0 0.001 100.0 0.01 /
```

```
-- The chaotic search needs to use
-- MAPSEARCH to define map points.
-- Since we have three parameters,
-- we require a three-dimensional map.
-- The following line defines the number of
-- division(or cells) along each dimension to be
-- 5, 4, and 5.
```

```
MAPSEARCH
 5 4 5 /
```

```
--
-- At every visit to a map point in a chaotic
-- search, one can conduct a gradient search.
-- The following line states conducting
-- 1 iteration for the gradient search with
-- the map point as the initial guess.
```

```
MAPSEARCHMAXITN 1 /
```

```
--
-- The following line explicitly defines
-- the parameters to be included in a gradient
-- search. The first and second parameters will
-- included, but the third parameter are not.
-- This is useful to exclude parameters that
-- are not eligible for analytical derivative.
```

```
NEWTONACTIVITY
 1 1 0 /
```

3c) Specify which property to be optimized and what type of data to be fitted to. Then, launch Koko. The results of the optimization are summarized in the case1.csv, case1.olst, and case1.orfttxt files. The case1.csv file can be plotted via Excel or any software that accepts a .csv file.

```
--
-- Porosity in WINDOW 1 5 1 4 1 2 is
-- assigned to be PAR#1
```

```

-- Porosity in WINDOW 1 5 14 3 3 is
-- assigned to be PAR#2
--
EQUALS
  POROS PAR#1 1 5 14 1 2 /
  POROS PAR#2 1 5 14 3 3 /
--
-- SWIR multiplier is set to Parameter 3
--
MULTIPLY
  'SWIR' PAR#3 /
--
DATES
  01 'JAN' 1940 /
--
-- Starting from January 1st 1940, water and gas
-- rates of well W1 are fitted to with a weighting
-- factor of 1.0
-- RFT pressures of well W1 are fitted with a
-- weighting factor of 0.5
--
DATAOPTM W1 CUMWATP CUMGASP 1.0
/
DATAOPTM W1 RFTMINP 0.5 /
DATES
  01 'JAN' 1941 /
--
-- Starting from January 1st 1941,
-- Water rate of well W2 is added to the data
-- pool to be fitted to with a weighting factor of
-- 0.5
--
DATAOPTM W2 CUMWATP 0.5 /
--
-- Conduct optimization until year 2050
--
DATES
  01 'JAN' 2050 /
STOP /

```

Step 4. Improve simulation results surrounding the wells during optimization

Add the following line to the RUNSPEC Section of the optimized Eclipse deck. Launch the optimization run.

```
RETAINWELLGRID 1 /
```

This instructs Koko to retain one ring of fine grid blocks surrounding wells during grid coarsening.

Note that in the absence of RETAINWELLGRID and FOCUSGRID (to be introduced next), Koko will only simulate the coarsest level of grid.

Step 5. Improve simulation results in one particular area of interest during optimization

Add the following line to the beginning of the RUNSPEC Section of the optimized Eclipse deck. Launch Koko.

```
FOCUSGRID 1 10 1 10 1 3 6 /
```

This instructs Koko to retain 6 rings of fine grid blocks surrounding wells for all wells in the window of 1 10 1 10 1 3. This overrides the number of rings defined in RETAINWELLGRID. However, if the number of rings is less than that defined in RETAINWELLGRID, the latter is used.

Step 6. Optimize well PI via a restart file

Add the following lines to the beginning of the Recurrent Data Section. Set up the restart file just like Eclipse and launch Koko.

```
DATAOPTM W1 MINBHP 1.0 /
DATAOPTM W2 MINBHP 1.0 /
WELLPIOPTM W1 / PAR#1 /
WELLPIOPTM W2 / PAR#2 /
```

The first two lines instruct Koko to fit to minimum bottom hole pressures of wells W1 and W2. The third and fourth lines instruct Koko to optimize on the divider of the well PI for these wells. Only divider of well PI can be optimized. Optimization of well PI cannot be mixed with optimization of other properties.

Optimization of well PI is generally considered to be the last stage in a history matching. Well PI is fitted to the bottom hole pressures towards the end of production history. Usually a few time steps before the end of production history

are required. Thus, users can use a restart file for such an optimization.

justified if excluding the earlier production data does not significantly affect the results.

Restart file can also be used for optimization of grid properties. However, this use can only be

List of Implemented Eclipse keywords

ADD	ADDREG	API	APIGROUP
BOX	COMPDAT	COORD	COPY
DATES	DATUM	DENSITY	DEPTH
DIMENS	DISGAS	DIVIDE	DUALPORO
DX	DXV	DY	DYV
DZ	DZV	END	ENDBOX
ENDSCALE	EQLDIMS	EQLNUM	EQLOPTS
EQUALREG	EQUALS	EQUIL	FAULTDIM
FIPNUM	FLUXNUM	GAS	GRAVITY
GRID	IMPLICIT	INIT	INPUTRS
KRG	KRGR	KRO	KRORG
KRORW	KRW	KRWR	MAXVALUE
MINVALUE	MULTIPLY	MULTIREG	NET
NTG	OIL	OILAPI	PBUB
PCG	PCW	PERMX	PERMY
PERMZ	PMAX	PORO	PORV
PRESSURE	PROPS	PVCO	PVDG
PVTG	PVTNUM	PVTO	PVTW
PVZG	REGDIMS	ROCK	RS
RTEMP	RUNSPEC	SATNUM	SCHEDULE
SGAS	SGCR	SGL	SGLPC
SGOF	SGU	SGUPC	SMRYDIMS
SOGCR	SOIL	SOLUTION	SOWCR
START	STONE2	SWAT	SWATINIT
SWCR	SWL	SWLPC	SWOF
SWU	SWUPC	TABDIMS	TITLE
TOPS	TRANX	TRANY	TRANZ
TUNING	VAPOIL	WATER	WCONHIST
WCONINJ	WCONINJE	WCONPROD	WELLDIMS
WELOPEN	WELSPECS	WPIMULT	ZCORN

New Koko Keywords

ANALYTICALDERIV	ARRAYDIMENSION	AUTOCOARSEN	AUTOCOARSENREST
CHAOTICSEARCH	DATAOPTM	FINEGRIDNAME	FOCUSCOMP
FOCUSGRID	GRIDDEFKOARSEN	GRIDFORMKOARSEN	MAPSEARCH
MAPSEARCHMAXITN	MIXEDFLUID	NEWTONACTIVITY	OPTMMAXITN
PAR#	PARALLELCHAOTIC	PINTERPOLATION	RETAINCOARSE
RETAINFINE	RETAINLGR	RETAINWELLGRID	RFTTFILE
VARIABLE1	WELLPIOPTM	XKOARSEN	XKRGCW
XKROCW	XKRWRO	YKOARSEN	ZKOARSEN

For questions and suggestions, please contact support@focussimulation.com.