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Estimation of time for the closed-loop implementation in complex reservoirs

Denis J. Schiozer

Introduction

Schiozer et al. (2019) proposed a twelve-step model-based closed-loop methodology to assist energy companies to improve production forecasts and the decision-making process under uncertainties. This process was summarized in the UNISIM Online nº 132, published in August 2019. Recent applications in complex reservoirs, representative of pre-salt fields with WAG-CO_2 injection, have shown the importance of a prior planning of the process to prevent delays and ensure the procedure is completed within a timeframe of real applications.

This text has the intention to (1) present a first version of an estimator of the time required to complete the process and (2) give hints of simplifications that can be implemented to speed-up the process.

Nomenclature

Here, we list the nomenclature used in this text.

- CL: closed-loop
- CLCO: closed-loop cycle optimization
- DAUR: data assimilation (DA) for uncertainty reduction
- FOFE: faster objective function estimators
- FPM: fit-for-purpose simulation models
- G1: design variables
- G2: control variables (G2L: life-cycle; G2C CL cycle)
- G3: revitalization variables (G3L: life-cycle; G3C CL cycle)
- HFM: high fidelity simulation models
- LCO: life-cycle optimization
- LFM: low-fidelity simulation models
- IAM: integrated asset modelling (integration between reservoir and production systems)
- RM: representative models
- STO: short-term optimization
- EVoI, EVoF: Expected value of information and flexibility

Description of the estimator to determine the total time required for a closed-loop implementation

We built an estimator of the total time required to complete the 12-step procedure (one loop of a CL practice) based on the parameters listed in Table 1. This is a first list of parameters and others may be required (more in-depth estimations can be done based on post-mortem analyses or previous tests). Although some parameters are self-explanatory, others require additional explanations: (1) E_f is a parameter used for time consuming processes, as we have to account for inefficiency in parallel computing, data preparation, data processing and business hours (5 instead of 7 days, 8 instead of 24 h for manual processes); (2) time estimation must include data preparation for use of tools.

The total time is a sum of all the times listed in Table 2. As our focus is the LCO, not the STO, we will consider the sum from Step 1 to Step 11. In the future, we can develop better estimators for t_{RC}, t_{FPM} and t_{DAP} but in this version we have concentrated the analysis in the repetitive steps (5-11). In step 6, t_{6a} is required only if the selection of a new base case is needed. For simplification purposes, we assume in the next section that the number of iterations for nominal and robust optimization is the same, local and global (it can be different for more efficient processes).

An approximation for the LCO time would be (or we can be the sum t_1 to t_{11}).

$$t_{LCO} = t_{rc} + t_{FPM} + t_{DAP} + t_{RM} + t_{IAM} + $$
$$+R_{PC}\,\{t_4\,(1 + i_{DA}\,) + 2 * t_{6a}\ + 2 * t_{6b} *\ i_{RM}]\}$$

Table 1: Definitions of parameters to estimate the time required for one loop of a CL practice.

E_f	Factor do adjust efficiency of time reducer
i_{DA}	Number of iterations of data assimilation process
i_{NGO}	Number of iterations of nominal global optimization
i_{NLO}	Number of iterations of nominal local optimization
i_{RGO}	Number of iterations of robust global optimization
i_{RLO}	Number of iterations of robust local optimization
n_{EF}	Number of models (ensemble) for “future” production forecasts
n_{EP}	Number of models (ensemble) for history period
$n_{proc.}$	Number of processors (for parallel computing)
n_{RM}	Number of representative models
R_{PC}	Time reducer (%) = E_f / n_{proc}
t_{DAP}	Time - data assimilation preparation (step 3)
t_{FPM}	Time - build the FPM (step 2)
t_{IMP}	Time - improvements to the final production strategy (step 11)
t_{IAM}	Time - IAM studies
t_{LCO}	Time - LCO
t_{RC}	Time - reservoir characterization (step 1)
t_{RM}	Time - RM selection
t_{SF}	Average runtime for one model - production forecasts
t_{SP}	Average runtime for one - history period
t_{ST}	Time - ST optimization (step 12)

Table 2: Time consumption of each step.

Step	
1	$t_1 = t_{RC}$
2	$t_2 = t_{FPM}$
3	$t_3 = t_{DAP}$
4	$t_4 = t_{SP} * n_{EP} * R_{PC}$
5	$t_5 = t_4 * i_{DA}$
6	$t_{6a} = t_{SF} * n_{EF} * R_{PC}$ $t_{6b} = t_{SF} * R_{PC} * (i_{NGO} + i_{NLO})$ $t_6 = t_{6a} + t_{6b}$
7	$t_7 = t_{6a}$
8	$t_8 = t_{RM}$
9	$t_9 = (n_{RM} - 1) * t_{6b}$
10	$t_{10} = t_{SF} * n_{RM} * (i_{RGO} + i_{RLO}) * R_{PC}$
11	$t_{11} = t_{MIP} + t_{IMP}$
12	$t_{12} = t_{LC} + t_{ST}$

Example

We are presenting a typical case of a complex reservoir with 3 hours of simulation runtime and parameters described in Table 3.

The time for each step is shown in Fig.1. The most time-consuming steps are steps 9 and 10 for nominal and robust optimization of the representative models. The total time for this case is almost 600 days. In Fig. 2, we show a range of total time variation considering a pessimistic and optimistic process yielding an estimation in the range of 540-770 days. The pessimistic and optimistic levels were obtained by multiplying the E_f by constant values assuming different efficiencies for the execution of the steps (these values can be estimated by users according to their experience in the problem). Even the optimistic case is too time consuming for a company that needs faster results. For instance, a good practice would be to have the result before the end of the CL cycle so the solution could be applied to the next cycle.

In Fig. 3, we present some simplifications that can be made in the process in Case 2 (LFM substituting FPM), Case 3 (simplified optimization process), Case 4 (fewer representative models), Case 5 (performing either robust or nominal optimizations, not both), and Case 6 (combining all simplifications). Each simplification has consequences in the final decision and we are doing research to quantify them. However, companies can use this estimator to have

***Table 3**: Parameter values used in the example. Case 1 is the base case, while Cases 2 to 6 consider different simplifications. Changes are highlighted for Cases 2 to 6.*

	Case					
	1	2	3	4	5	6
E_f	1,3	1,3	1,3	1,3	1,3	1,3
i_{DA}	4	4	4	4	4	4
i_{NGO}	2000	2000	1000	2000	2000	1000
i_{NLO}	500	500	250	500	500	250
i_{RGO}	2000	2000	1000	2000	-	1000
i_{RLO}	500	500	250	500	-	250
n_{EF}	200	200	200	200	200	200
n_{EP}	100	100	100	100	100	100
n_{proc}	16	16	16	16	16	16
n_{RM}	9	9	9	5	9	5
t_{DA} (d)	30	30	30	30	30	30
t_{FPM} (d)	30	30	30	30	30	30
t_{IMP} (d)	15	15	15	15	15	15
t_{MIP} (d)	5	5	5	5	5	5
t_{RC} (d)	60	60	60	60	60	60
t_{RM} (d)	1	0,17	1	1	1	0,17
t_{SF} (h)	3	1	3	3	3	1
t_{SP} (h)	0,5	0,5	0,5	0,5	0,5	0,5

an idea of the time required and scale the application so that it is compatible with the necessity of each study.

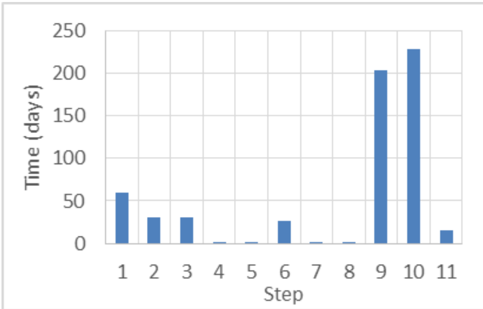

***Figure 1**: Time execution of each step.*

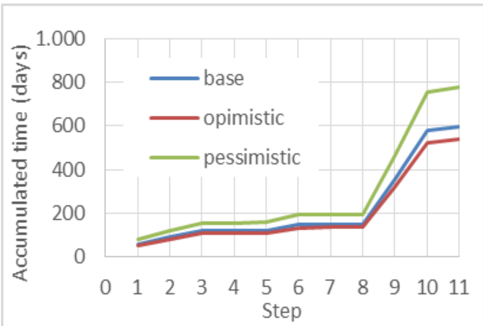

***Figure 2**: Accumulated time for 3 scenarios.*

Suggestions for simplifications

Some suggestions that were tested and that can be applied to speed up the process are:

- Use of LFM to substitute FPM in parts of the process;
- Use of FOFE (proxies, emulators, …) to substitute simulations in part of the process;
- More effective optimization algorithms;
- More efficient data assimilation process;
- Better infrastructure (computers, # licenses, human resources, …);
- Software to reduce preparation time;
- Decrease the number of models in the ensembles;
- Decrease the number of RM;
- Use only one optimization process, nominal or robust (Step 9 or 10; remembering that we need both to properly estimate VoI and VoF);
- Separate variables (G1, G2 and G3; and LC, CL, ST variables) to give more emphasis in the most important ones for each study.

Some examples of LFM are (remembering that we must always go back to FPM or even HFM for the final decision):

- Black-oil replacing compositional models;
- Single-porosity models to represent dual-porosity and dual-permeability models;
- Coarser grids;
- Numerical tuning and simplification to accept more approximate solutions.

Some examples of FOFE are (remembering that we use FOFE to only reduce the search space assessed using simulation models):

- Bayesian emulators;
- Statistical planning and response surface models;
- Shorter simulation time, especially for life-cycle objective functions (for instance, in half of reservoir´s life, we already know if a solution is bad);
- Machine learning and neural network.

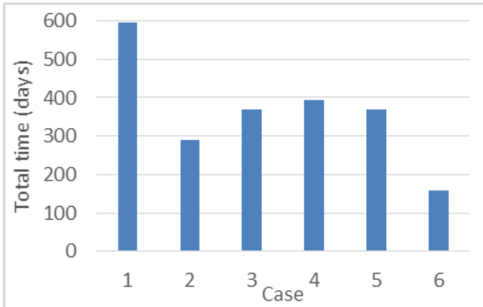

***Figure 3**: Total time for 6 cases (1 – original; 2-6 with simplifications).*

Concluding Remarks

This UNISIM ONLINE is important as an alert to the implementation of the model-based field management process, which is being improved over the years. The alert is to users to build a process that is viable in terms of time implementation, demanding simplifications that have to be carefully studied to have a balance between quality of the results and execution time.

The focus is initially in the life-cycle optimization but we well also check the impact on short-term decisions and we will try to have better indications of the impact of each simplification in each specific situation.

We will also try to improve the quality of the time estimator based on future applications.

Acknowledgments

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References

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