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"UNISIM default classification for simulation models and fast-objective-function estimators is presented to be used in the 12-steps methodology in geological and simulation model (SM) updating and production optimization under uncertainties."

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Simulation Models and Fast Objective Function Estimators Classification for Petroleum Reservoir Studies

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In many situations across reservoir engineering and other sciences, multiple reservoir numerical models are available to model the physical behaviour of petroleum fields.

The general idea of integrating all these areas is to build reliable numerical models for predicting hydrocarbon reservoir performance under various operating strategies and uncertainties.

Schiozer et al. (2019) proposed a twelve-step methodology to assist oil company employees and research scientists in geological and simulation model (SM) updating and production optimization under uncertainties. One of the most important steps of that methodology is the construction of a model that fits the purpose of representing the best benefit-cost relationship in terms of the importance of the study, available time and resources.

In the best practice, a high-time consuming simulation model is created to honour a geological model, but it is not viable to run this model several times in practical applications such as uncertainty reduction, production forecast and decision analysis. Creating a faster model is then the solution for this time-consuming scenario. Besides, hundreds of these models can be created as an alternative to save even more computational time, such as simplified physics approximation, reduced model and data-fit surrogate.

With the increasing use of these models, we observe that there is a lack of a model's classification in the entire workflow to speedup geoengineering studies when multiple models, uncertainties, and production system facilities are combined. Table 1 summarises the fidelity model classification of UNISIM for reservoir simulation (RSM) and Production System Simulation (PSSM) in high, medium and low-fidelity. They are a representation of the physical phenomenon.

***Table 1**: UNISIM default fidelity model classification: reservoir simulation (RSM) and production system simulation (PSSM)*

Model	Abbreviation	Characteristic
High-fidelity	HFM	computationally expensive and high-accuracy
Medium-fidelity	MFM	suitable running time and accuracy
Low-fidelity	LFM	fast to run and less accurate

The **high-fidelity model (HFM)** is created with all information and high-level of details of the reservoir, production system or both to represent better the real field. This model is high-time consuming, and it runs to estimate an output with the accuracy that is necessary for the current application. Usually, it runs a few times to collect information, validate methodologies, calibrate other lower-fidelity models, or combine with different models and objective-function estimators.

The **medium-fidelity model (MFM)** arises from the high-fidelity model and estimates the same output quantity as high-fidelity, but with a reduced computational effort and also accuracy. For our group, we defined that **this model is the type chosen by the petroleum industry created by the geoengineering and the production team**. In our group, this model is recommended for applications that do not demand several runs, such as probabilistic approaches.

The **low-fidelity model (LFM)** is built when we need to accelerate the process. This model estimates the outputs with lower accuracy than the medium-fidelity model typically in favour of reduced run time when several runs are necessary. All simplifications performed in the SM to speed up a process is treated as LFM. They are obtained, for example, by simplifying physics, fluid models, coarser domains, assuming less refinement in some regions of the reservoir, production system or both, and numerical model simplifications.

We can also generate the objective functions estimated by the simulation models that tend to represent the real system (petroleum field) from other simplified versions that we are calling fast-objective-function estimators.

Fast-objective-function estimator (FOFE) included all model versions faster than the low-fidelity simulation model to estimate outputs with a lower computational cost. A wide variety of modelling approaches exist in the literature that raises the idea that FOFE is not an only physics-based model, but also analytical and hybrid ones. Table 2 presents the FOFE classification.

"Simulation models and fast-objective-function estimators classification is presented to be used by UNISIM's group and also oil company employees and research scientists representing the best benefit (fit-for-purpose) among reservoir simulation study objective, available time, and computational and human resources."

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***Table 2**: UNISIM default classification for Fast Objective Function Estimator (FOFE)*

FOFE	Abbreviation	Model's Characteristic
Proxy	PROXY	analytical
Emulator	EMU	analytical
Hybrid physics-based and data-driven	HPDM	physics-based and data observation
Hybrid physics and analytics-based	HPAM	physics-based and analytical

Proxy models (PROXY), also known as surrogate and metamodels, are analytical functions that provide an estimate of an objective function from the simulation model. Surface response methodology, polynomial regression models, ordinary kriging models, artificial neural networks and radial basis functions are examples of proxy models. The quality will depend on the mathematical approach, the input used to build it, and the complexity (linear or nonlinear) of systems modelled.

Emulator (EMU) is a statistical approximation of an objective function, providing both an estimate and an uncertainty statement about that estimate. New evaluations with these models are possible to perform an order of magnitudes faster than FRSM. The combination of emulator and simulator enables to identify the non-implausible regions that are compatible with observed data and uncertainties mapped.

Hybrid physics-based and data-driven model (HPDM) takes advantage of both physical phenomenon (flow in porous media or tubing) and data observations (real data from the petroleum field) for standard practices in reservoir and production system simulation. The HPDM is a new field of research that combines the interpretability, robust foundation and understanding of a physics-based modelling approach with the accuracy, computational efficiency, and pattern-identification capabilities of data-driven. This model generally uses machine learning and artificial intelligence algorithms.

Hybrid physics and analytics-based model (HPAM) has both physical phenomena and mathematical formulations. HPAM is also a new area because it is possible to combine the learning from the physical behaviour and the analytical formulations, such as the PROXY and EMU, to predict the effect of a complex physical interaction that happens through the time in the simulations. The idea is not replacing the physics-based by analytics-based model, but also integrate both to get more accurate and precise estimations of the objective functions and the uncertainties.

All in all, it seems to us that it is essential to create a standard terminology to distinguish between the full physics-based simulation model and analytical and hybrid ones that tend to be faster than the simulation models. So, this standard terminology of simulation models and fast-objective-function estimators can guide our studies to select a model (fit-for-purpose) to represent the best benefit based on simulation study objectives, available time, and computational and human resources.

Reference

Schiozer, D. J.; Santos, A. A. S.; Santos, S. M. G.; Hohendorff Filho, J. C. V. 'Model-Based Decision Analysis Applied to Petroleum Field Development and Management', Oil & Gas Science and Technology, v. 74, pp. 1-20, Maio, 2019.

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