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# PetroBayes' Modules for Reliability Assessment for Oil and Gas Industry

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PetroBayes is user-friendly software that performs Bayesian reliability estimation. The software comprises three main modules that can provide the reliability measures. The first, the Bayesian module, enables the user to assess the variability distribution of non-homogenous failure data. In this module, one can obtain a prior distribution for the reliability measure of interest based on generic data; the posterior distribution is a result of the update procedure with specific information of the system of interest. The Statistical module can fit data into distributions (e.g., the duration of maintenance actions) and perform statistical tests (e.g., goodness of fit). The Availability module can be fed with data from the previous models to build a continuous time homogenous semi Markov process (CTHSMP) and estimate the system's availability. The failure rate can be derived from the Bayesian module, while the repair rate, from the Statistical module in a straightforward workflow. Note that these rates need not to be constant (i.e., exponentially distributed), thus allowing a more robust assessment. All the results can be displayed to the user, be given in written reports and images. The software can be hosted on a remote server, minimizing the usage of the user's own computation resources. We illustrated the use of the Availability module considering generic databases.
*Keywords*: Bayesian analysis; Weibull distribution; Availability assessment; Web-based app; Oil & Gas industry.

## 1. Introduction

Continuous time homogenous semi-Markovian processes (CTSMP) are important tools in the context of reliability engineering, since it allows modeling the future behavior of systems only as a function of the current and next state that the system will occupy, as well as the time of permanence in that state. Thus, it was feature required in our under development software, the *PetroBayes,* that performs Bayesian reliability estimations.

The novel module for availability assessment was developed to be able to assess the behavior of a given system over time, obtaining the availability of the system, i.e., the probability, over a given mission horizon, in which the system remains in the state (or set of states) that it can perform within a desirable level. Therefore, to improve the flexibility of the model, the transition rates will not necessarily follow exponential distributions, but rather they can follow any distribution, providing a broader range of applications. We also included repair rates as events to recover the system from failures or degradation. This approach complements the work detailed by Santana et al. (2022) as illustrated in Fig.1.

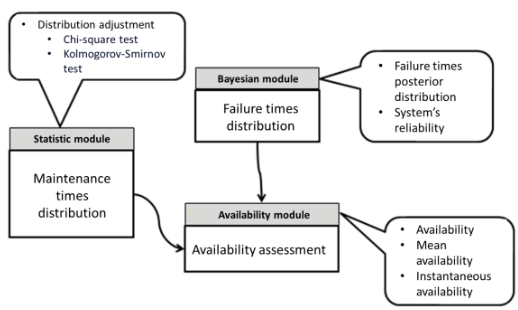


Figure 1. Integration between Petrobayes' modules.

## 2. Methodology

We build a CTHSMP described by transition rates between states (Moura & Droguett, 2010). The model structure can be chosen from three available options (Table 1). The decision regarding which model to choose relies on the data available, which dictates the complexity required to parameterize it, the level of. The state probabilities are obtained through Monte Carlo simulation.

Table 1. Summary of the models implemented in the module for availability assessment

| Model | State description |
|---|---|
| 2-states | Operational (0) and Failed (1) |
| 3-states | Operational (0), Degraded (1) and Failed (2) |
| 4-states | Operational (0), Degraded without downtime (1), Degraded with downtime (2) and Failed (3) |

## 3. Results

To illustrate, we considered the 3-state case. The failure rate is obtained from the Bayesian module (Santana et al., 2022), and the repair rates by fitting the repair time in probability distributions. The transition from $0 \rightarrow 1$ is described by $Exp(\lambda_1 = 0{,}000389/h)$; $1 \rightarrow 0$ by $LogN(\mu_{10} = 1{,}49, \sigma_{10} = 1{,}00)$, $0 \rightarrow 2$ by $Weibull(\alpha_{02} = 500h, \beta_{02} = 2{,}35)$; and $2 \rightarrow 0$ by $LogN(\mu_{20} = 0, \sigma_{20} = 0{,}91)$ Fig. 2 depicts the 3-state CTHSMP.

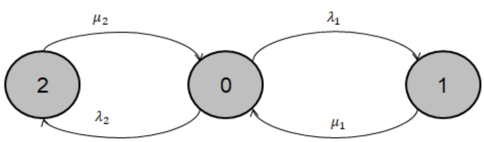


Figure 2. Semi Markovian system with 3 states.

The results were obtained considering a time horizon $T = 2.000h$, and $M = 100.000$ Monte Carlo replications. The main reliability metrics are given in Table 2 while the availability and unavailability are presented in Fig. 3.

Table 2. Reliability metrics obtained in the availability module

| Metric | Values |
|---|---|
| Mean operational time (h) | 1994.23 |
| Mean failed time (h) | 5.77 |
| Mean unavailability | 0.0029 |
| Mean availability | 0.9971 |

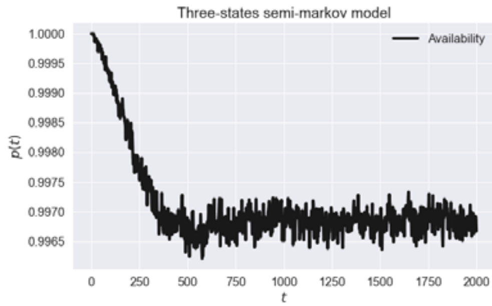


Figure 3. 3-state system's availability.

## 4.Conclusion

The novel module seeks to combine treatability and relevance in the results, ranging from simpler models to more complex models, better capturing the conditions to which the system may be subject. With this, the flexibility of the model allows it to adapt to the circumstances and needs of the user. Additionally, a visual analysis is provided to support the decision making.


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