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Task-based Model Selection/Optimisation

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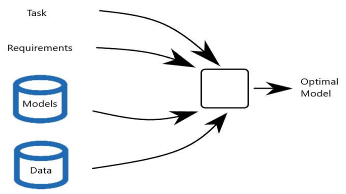
❑ General Problem

- Complex systems are usually modelled through high-fidelity high-cost models, used mainly for simulations
- Each model recreates one behaviour of the system, also known as **mode**.
- A real system has many different operative modes. e.g. a drone's modes: take-off, landing, wandering, surface mapping, etc..

$$\text{Modes: } \begin{cases} y_{m_1} = g_1(x) \\ \vdots \\ y_{m_i} = g_i(x) \end{cases}$$

➢ Given a specific task, which allows multiple operating modes, create a simple model m, such that:

$$m = arg \max_{m_i \in M} [\alpha \cdot Accuracy(m_i) + \beta \cdot Cost(m_i)]$$



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❑ State of art

Currently the problem is approached through:

- **Surrogate models:**
  Data-driven approach to extract a simpler model of one mode of the system.

- **Ensemble of models:**
  Optimisation of surrogate models to achieve higher accuracy using a small amount of high-fidelity model data.

- **Forward simulation on single independent modes:**
  Data prediction of a known mode.
  Focused on studying the effects of a single active mode per simulation.

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❑ Goals

- **Inverse inference:**

$$\text{Forward: } y = g(x)$$
$$\text{Inverse: } x = g^{-1}(y)$$

The inverse inference is difficult also when g is linear.
In our problem g is most of the time non-linear, increasing even more the inverse inference complexity.

- **Multi active modes:**
  Extending the forward simulation to include different modes at the same time.

$$\left.\begin{matrix} y_{m_1} = g_1(x) \\ \vdots \\ y_{m_i} = g_i(x) \end{matrix}\right\} \Rightarrow y_{m_m} = \sum_{m_i \in N \subseteq M} \alpha_i \cdot y_{m_i}$$

- **Inverse inference on multi active nodes:**
  Extending the inverse inference to a multi active modes scenario, increasing the process difficulties due to eventual synergies between modes.

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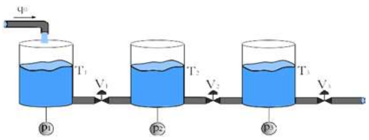
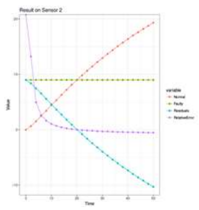
❑ Achievements

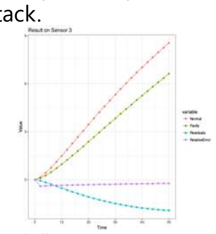
All experiments are based on the three tanks model system, a common problem based on a non linear model.



1. Non linear vs linear models:
   Based only on data gathered from simulation, we simplified the non linear model to a linear one.

2. Attacks vs. Faults isolation:
   Inverse inference application to identify if the system is having some internal faults or is under attack.





Examples: An easy to detect attack on a sensor (left image); synergies of different active modes on the system creates similar to normal behaviour of the system, making them harder to detect (right image).

❑ Future work

Use machine learning to improve the mode identification process.

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