Data-driven monitoring of Systems-On-Chip for Multifunction Modular Cockpit Display

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Introduction:

The ubiquity of microprocessor-based and embedded systems inspired research about their monitoring and reliability, notably in safety-critical systems. This work is a part of a project to develop touchscreens for futuristic cockpits, in which, we focus on the supervision and monitoring of the Systems-on-Chips (SoCs). We create a monitoring framework to detect drifts and faults in the behavior of the heterogeneous SoC (CPU and GPU). Firstly, we built an incremental interconnected model to estimate a set of characterizing variables for the chip. Then this model is associated with a fault detection algorithm. Estimations from the model constitute inputs to the diagnosis module. The latter generates alarms in the presence of faults or drifts in the characteristics and features of SoC. The obtained results validate the proposed monitoring algorithm and demonstrate the effectiveness of the fault detection algorithm.

Objective: The Cockpit of the future:

- A user-friendly interface with touchscreens
- Displays to provide pilots with intuitive interactions
- Be able to accommodate the complex functions of the aircraft and systems

Main lines of research:

- Incremental modeling of variable structure systems
- Characteristics drift detection
- Life Cycle Optimization (MTTF Optimization)
- Estimation of the Remaining useful life

Online supervision through Analytical redundancy:

- A reference model runs in parallel to the system
- The outputs from the model are compared with outputs of the system
- Though this comparison results in Residuals
- The state of the system is deduced by analyzing these residuals
- The residuals are also indicators of diagnosis and prognosis of the system

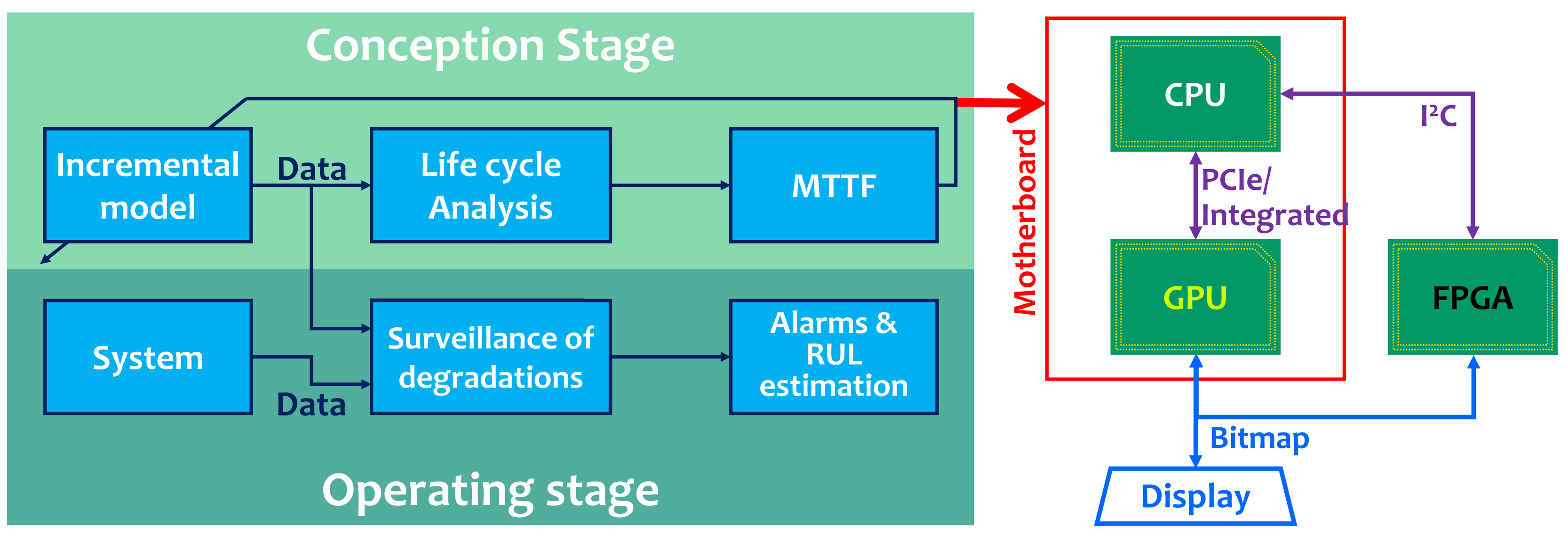

Fig 1. Monitoring and analysis of an embedded system

Modeling :

- Exploiting the causal relationships between variables for simpler incremental modeling [Fig 2]

$$Frequency \rightarrow Voltage \rightarrow Power \rightarrow Temperature$$

- The model is adaptable and portable to all devices with same architecture
- Easy swapping of sub-model to adapt to different operating modes and devices
- Use of black-box and machine learning rather than white-box for simplicity and performance
- Need to accommodate 20 ms sampling Real-time sampling time

Variable	Model type	Performance
Frequency	Algorithm	$MAE = 0\%$ Max Delay = 80 ms
Voltage	Look-up table	$MAE = 0\%$ Max Delay = 110 ms
Power	NARX Neural network	$MAPE = 2.8\%$
Temperature	ARMAX	$MAPE = 0.8377\%$

Monitoring residual evaluation :

- Comparison of the estimation to measurements ➔ Raw residuals

$$r_x = (x_{estm} - x_{meas})/x_{estm}$$

- Residuals are processed to avoid false alarms due estimation errors (P and T):

$$r_{m_x} = \frac{1}{n}\sum_{i=1}^{n} r_x$$

- Threshold are computed statistically, that if surpassed an alarm is generated

$$th_{r_x} = \mu \pm 3 \times \sigma$$

Results and conclusion :

- Both the model and the monitoring frameworks are validated [Fig 2]
- The monitoring framework detects an array of driver, environment, and system faults
- Program deployed to and validated on multiple different devices
- Future works will focus on the diagnosis and remaining useful life of the system

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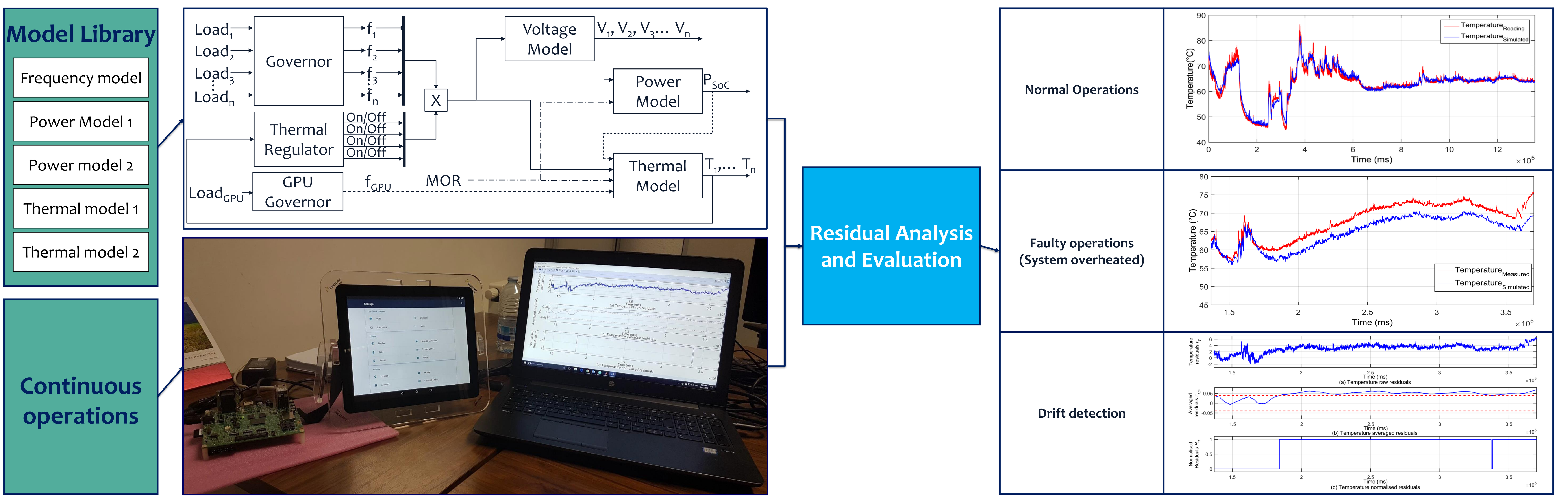

Fig 2. Interconnected and Incremental modeling and online monitoring

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