Fault-Adaptive Control for Robust Performance Management of Computing Systems

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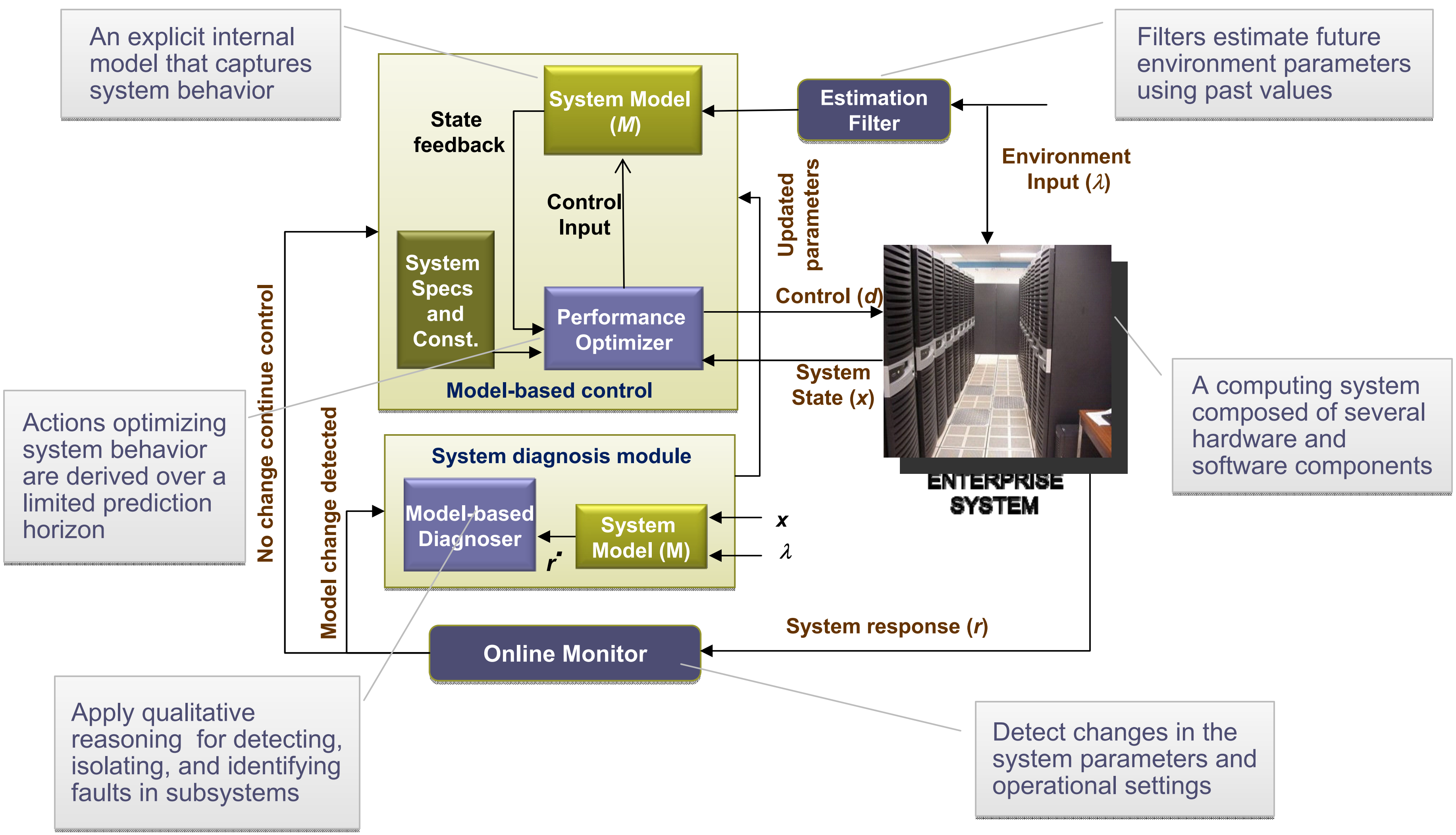
The Fault-Adaptive Control Structure



System Modeling

- Many practical systems exhibit a hybrid behavior comprising both discrete-event and continuous dynamics.
- In addition, control or tuning options must be chosen from a finite set at any given time.
- The dynamics of such systems can be captured formally as class of hybrid systems with finite control set; switching hybrid systems.

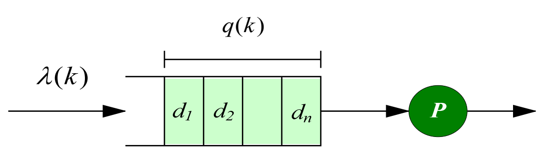
The dynamics of a switching hybrid system is represented by:

$$x(k+1) = f(x(k), u(k), \omega(k))$$

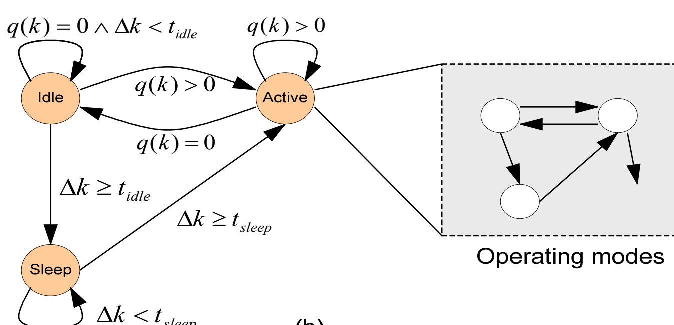
Where $x(k)$ is the state at time k, $u(k)$ is the control input chosen from a finite set U, and $\omega(k)$ is the environment input.

Environment inputs are typically estimated at time k based on previous values.

Operation requirement (specification) is represented as a set point or utility function.



(a)



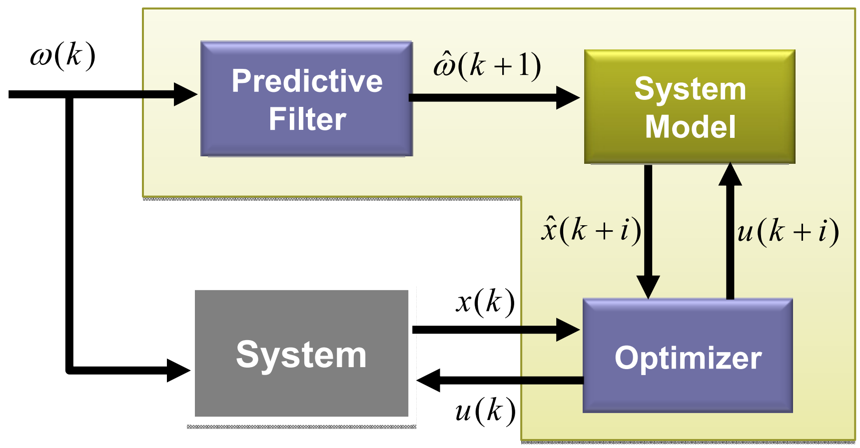
(b)

$$\hat{q}(k+1) = q(k) + \left(\hat{\lambda}(k) - \frac{\phi(k)}{\hat{c}(k)}\right).T(k)$$

$$\hat{r}(k+1) = (1 + q(k)).\frac{\hat{c}(k)}{\phi(k)}$$

$$\psi(k+1) = \phi^2(k)$$

Limited Lookahead Control



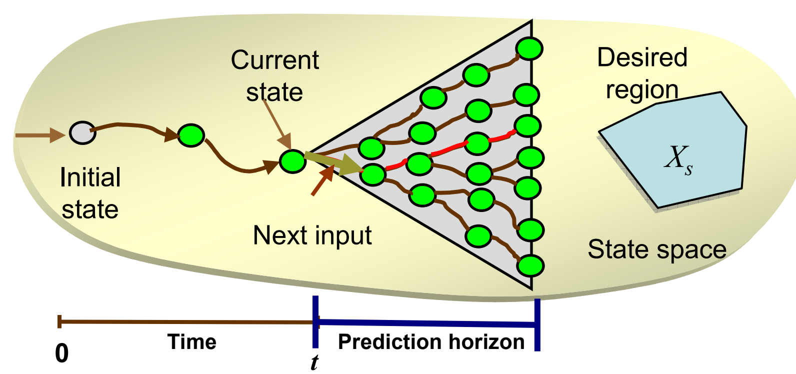
- Selection of the next step is based on a map that defines how close the current state is to X_s
- Controller constructs a tree of all future states up to certain depth.
- A path that minimizes the distance to X_s is traced back to current state and the initial step is selected.

Given a switching hybrid system with state space X and control input U. The control problem for a set point X_s is to:

- Drive the system from any state in X to X_s in finite time using inputs from U.
- Maintain the system in X_s

In the case of utility specification, the controller aims to reach the optimal state that maximizes the system utility.

$$\text{Minimize } \sum_{i=k+1}^{k+N} J(x(i),u(i))$$
$$\text{Subject to. } \hat{x}(i+1) = f(x(i),u(i),\hat{\omega}(i)),$$
$$. \; H(x(i)) \leq 0, u(i) \subset U(x(i))$$



Model-based Diagnosis

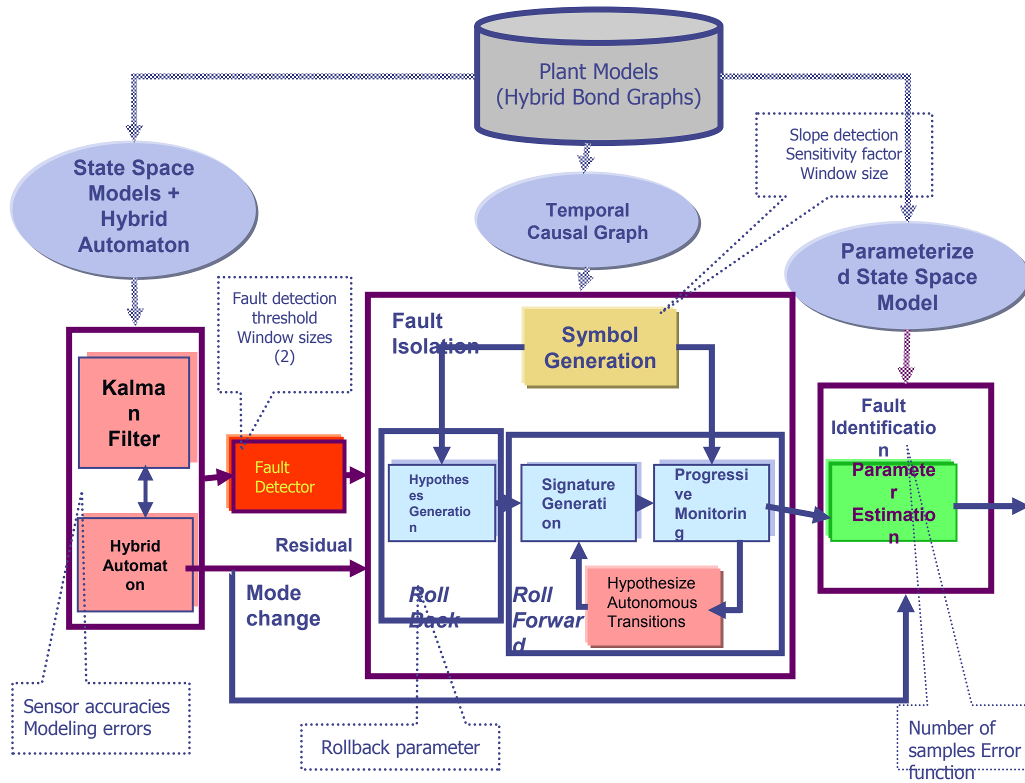
Qualitative reasoning

- Robust reasoning mechanisms are combined with quantitative parameter estimation schemes for fault isolation
- The switching hybrid model is used to generate parameterized Timed Causal Graphs (TCG)

Quantitative analysis

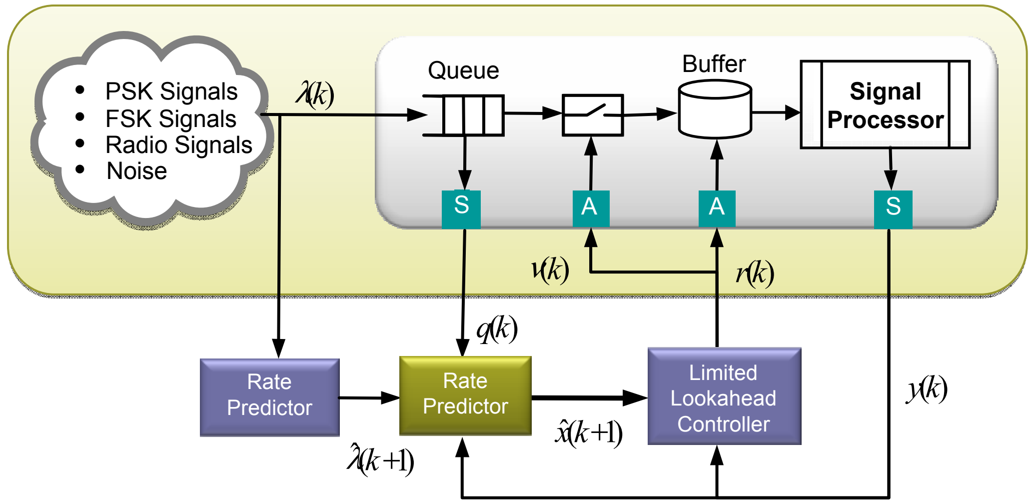
- Deviated parameter values are estimated for each fault candidate
- The state space equations are rewritten in terms of the parameter associated with the fault candidate, and least squares estimation techniques are used to derive the faulty parameter value
- A new parameter estimator is initiated for each fault hypothesis

- Uses the observed divergence between the actual system and the corresponding models to isolate and characterize possible failures as well as the set of possibly corrupted resources

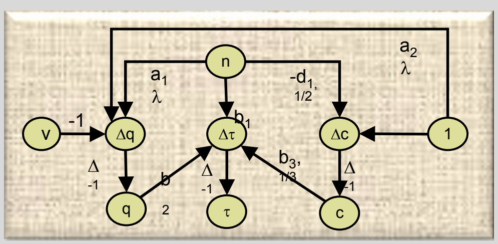


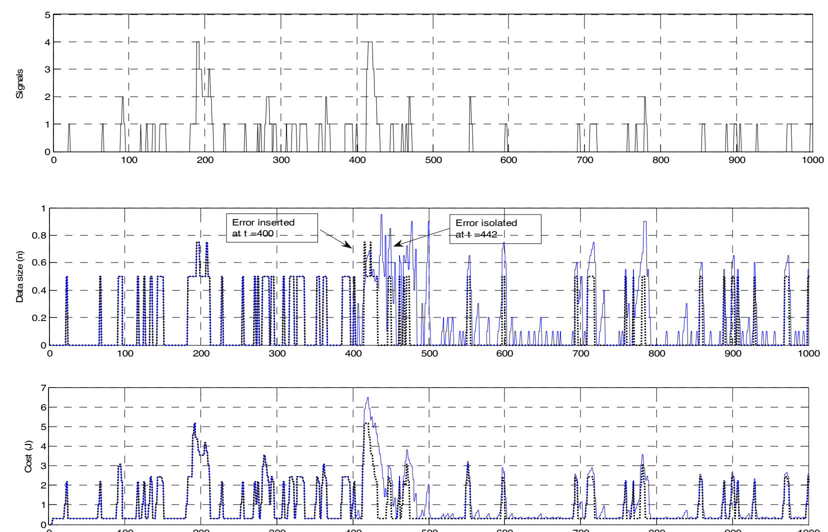
Application: Signal Detection System

- **Objective:** identify relevant data from incoming signals, received at a time-varying rate
- Detection accuracy and computation time depend on the signal size
- The controller must minimize the latency while maximizing accuracy



$$\hat{q}(k+1) = q(k) + \hat{\lambda}(k)[a_1 n(k) + a_2] - v(k)$$
$$\hat{\tau}(k+1) = \tau(k) + b_1 n(k) + b_2 q(k) + b_3 c(k)^{1/3}$$
$$\hat{c}(k+1) = c(k) - d_1\sqrt{n(k)} + d_2 v(k) + d_3$$





Thank You