Concepts and theorems of the Embedded Model Control

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Abstract

Modern system and control theory have clarified meaning and role of state equations as real-time models of artificial/natural phenomena. As such state equations can run in parallel to and synchronized with a phenomenon, subject to the same command. Ignorance about phenomenon (plant in the engineering field) can only be detected by comparing plant and model output in the form of a model error signal. Ignorance must and can be reduced to the benefit of stability, performance and identification by augmenting the command-to-output model (controllable dynamics) with a 'disturbance' model driven by arbitrary, but bounded signals (to be designed) that may be referred to as noise. The disturbance state becomes the current repository of the best knowledge of the past ignorance, to be real-time updated and capable of providing prediction. The only way of keeping updated the ignorance repository passes through the model error, as it is the only signal encoding the residual ignorance (a concept extending Kalman innovation). To this end a noise estimator must be designed closing the loop around the embedded model: the ensemble of the latter and noise estimator plays the role of state predictor and becomes the only source of information together with reference data (from a reference generator) to the control law in charge of synthesizing command to plant and embedded model. Embedded Model Control founds on such concepts, for designing and implementing any control unit around the embedded model, i.e. the ensemble of controllable and disturbance dynamics. The essential and modular EMC architecture naturally descends as in Figure 1.

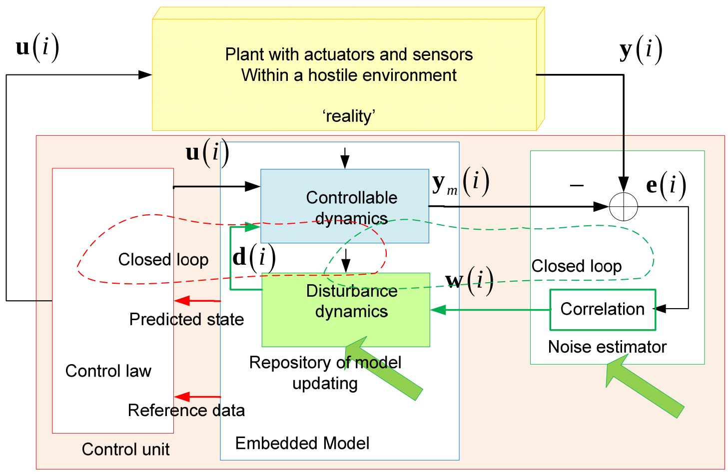

Figure 1 EMC essential architecture (referencedata generator is missing).

As a result control law and noise estimator are the model-to-plant and plant-to-model interfaces, whereas the reference generator is the operator-to-model one. Each of the three interfaces is directly imposed by the embedded model, and thus has minimal order (think of the H-infinity complex controllers). Further their tunable gains are feedback gains and must be tuned by fixing closed-loop eigenvalues (the intimate property of any dynamic system). The need of a robust stability and performance design becomes mandatory because of the modeling ignorance that is hidden in the model error being command dependent. The hidden ignorance must be given a sufficiently accurate model outside the embedded model (design model) driving the eigenvalue selection. It is shown that the modelled ignorance (structured, unstructured,…) enters the so-called error loop, a loop of error signals (Figure 2), to be stabilized versus the class of modelled ignorance.

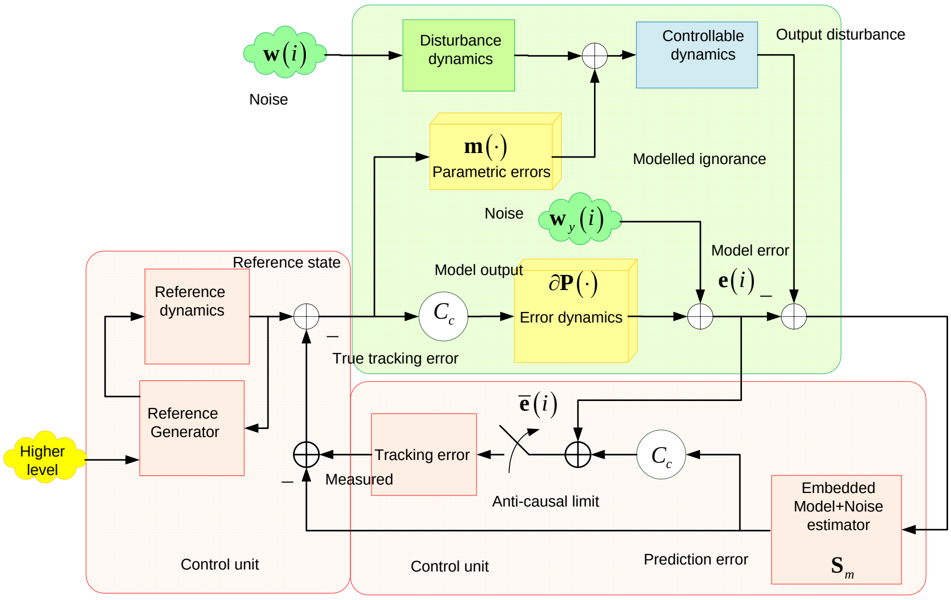

Figure 2 The error loop.

Stability and performance inequalities are then be established, that are analogue to H-infinity design, but encoding the minimal-order structure imposed by the embedded model. Interplay between state predictor and control law sensitivity, and their bandwidth, becomes clear as well as feedback degrees of freedom. Simple simulated and experimental results will enlighten the main results.

Short biography

Enrico Canuto received his degree in Electrical Engineering from Politecnico di Torino, Turin, Italy, where he joined the staff as an Associate Professor of Automatic Control in 1983. From 1982 to 1997, he contributed to data reduction of the European astrometric mission Hipparcos. Technological studies in view of scientific and drag-free space missions, like Gaia and GOCE, provided the opportunity of applying embedded model control to drag-free satellites and to electro-optics. He contributed to the conception, design and implementation of the Nanobalance interferometric thrust-stand, capable of sub-micronewton accuracy. Presently, he is involved in the design of the orbit, formation and attitude control of the Next Generation Gravity Missions of the European Space Agency. His research interests cover all the entire field of control problems that are challenging because of complexity, uncertainty and precision.

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