The innovative methodology and the ACODUASIS project

Francesco Donati
Politecnico di Torino

THEORETICAL FUNDAMENTALS

GAP BETWEEN THEORY AND PRACTICE

THEORY

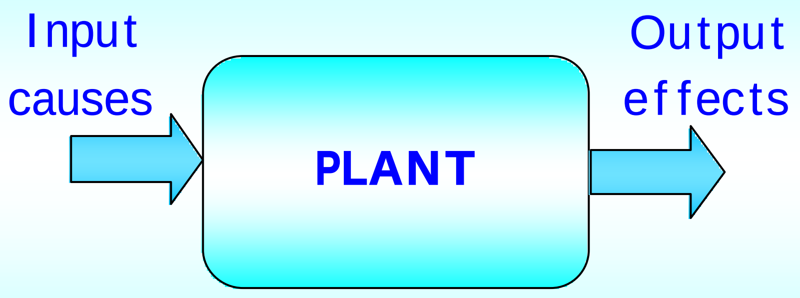
SOPHISTICATED AND POWERFUL CONTROL ALGORITHMS MAY BE DESIGNED FOR **“DYNAMIC SYSTEMS”**

BUT THEY ARE NOT USED IN PRACTICE

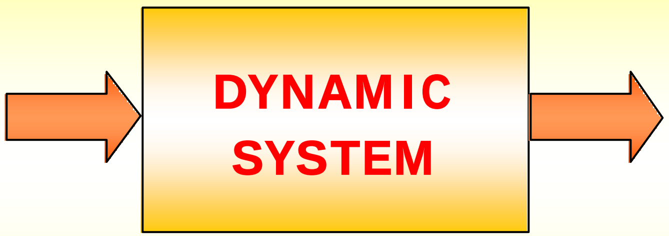
PRACTICE

SIMPLE CLOSED LOOP CONTROL ALGORITHMS (SUCH AS P.I.D.) MAY BE SUCCESSFULLY IMPLEMENTED BY PERFORMING AN EXPERIMENTAL TUNING HAVING ONLY A RAW KNOWLEDGE OF THE **“PLANT”** DYNAMICS

THEORETICAL FUNDAMENTALS



It is an object belonging to the real world



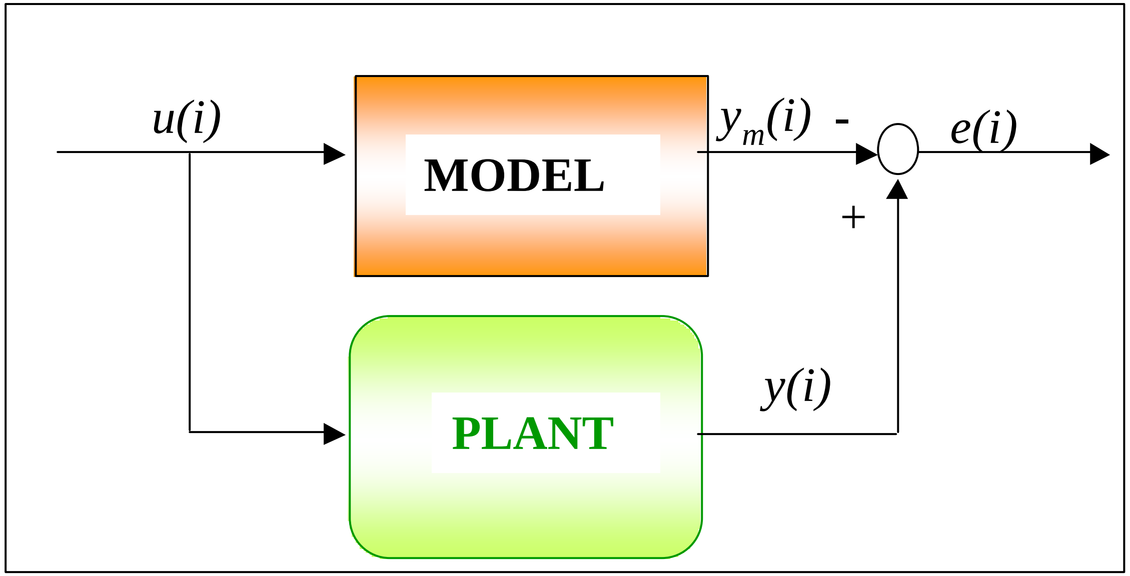
It is an object belonging to the mathematical world

See
"DYNAMIC SYSTEMS"
according to the KALMAN definition
1969

THEORETICAL FUNDAMENTALS

PLANT-MODEL UNCERTAINTY

Models can give only an approximate description of the related plant dynamics



A **plant-model uncertainty** always exists, which causes an error $e(i)=y(i)-y_m(i)$.

The **plant-model uncertainty** is said to be ***"NORM BOUNDED"***

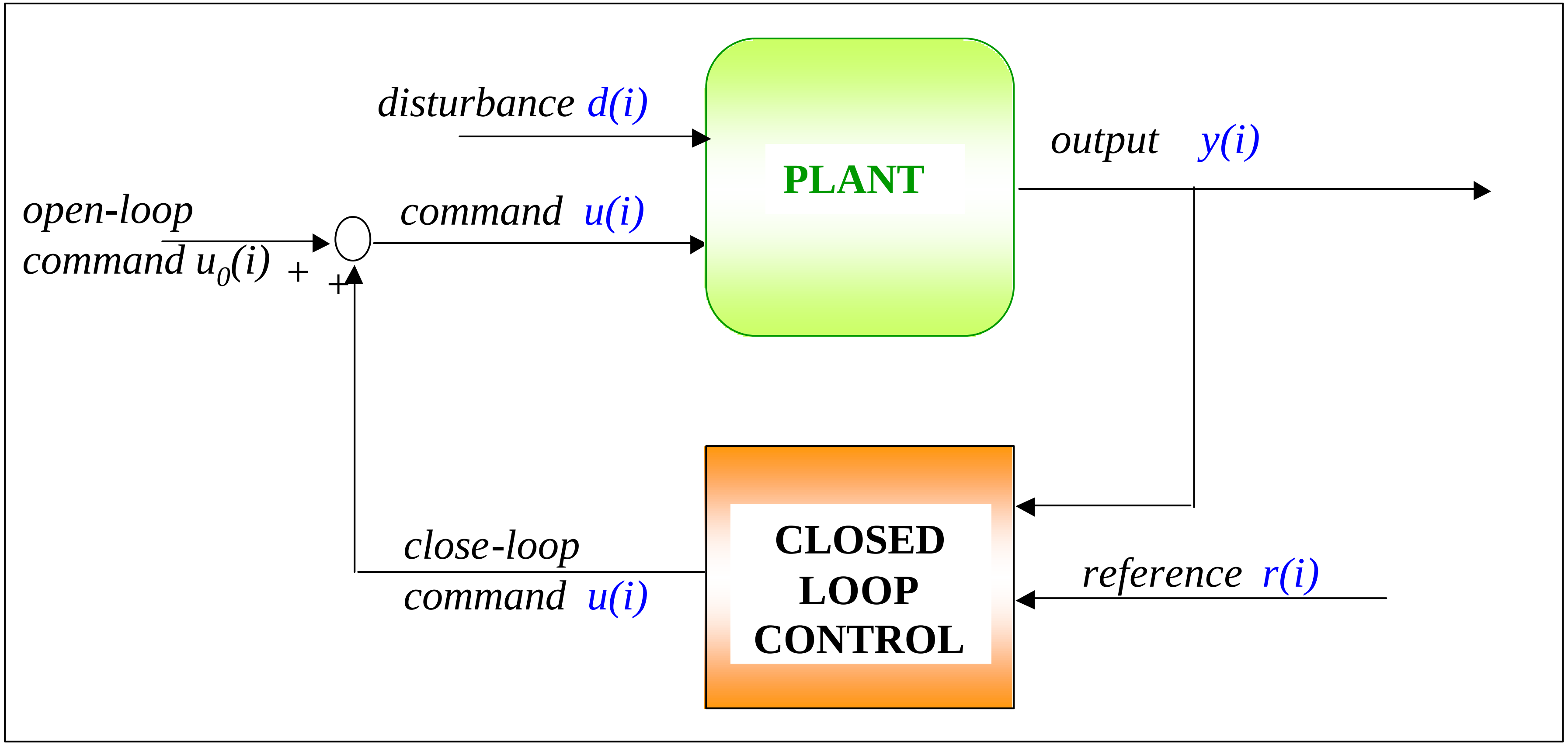
$\exists$ finite **E** and **D**

$$||y-y_m|| < E\ ||y_m|| + D$$

$\forall u(i) \in U$ and $\forall$ admissible operating conditions

THEORETICAL FUNDAMENTALS

CONTROL PERFORMANCE DEFINITION



attenuation factor Q

$$||r-y|| < Q\ ||r-y_0||$$

Where y_0 denotes the plant output in the absence of closed loop control, that is for $u(i)=0$

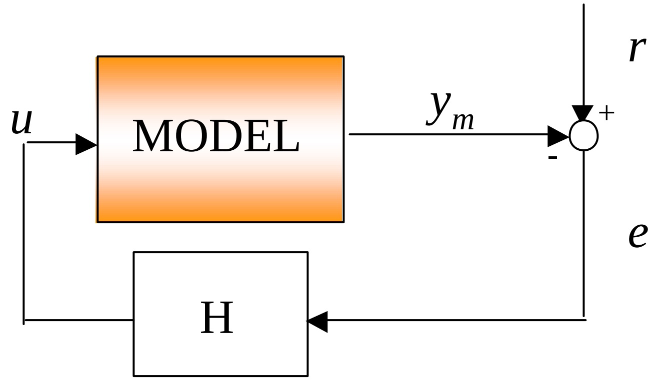
THEORETICAL FUNDAMENTALS

THE FUNDAMENTAL THEOREM

DONATI – CARLUCCI [1975] & DONATI – VALLAURI [1984]

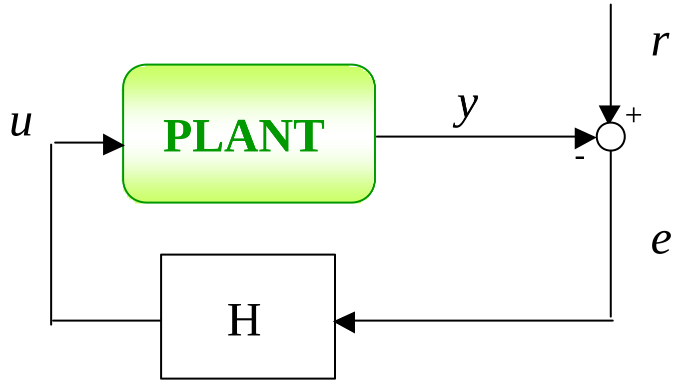
If

- ∃ a controller H such that $||e|| < Q||r|| \ \forall r \in R$
- $E < 1/(1-Q)$



Then the same controller applied to the plant is stable and produces an attenuation of a factor Q*

$$Q^* < \frac{Q}{1 - E(1+Q)}$$



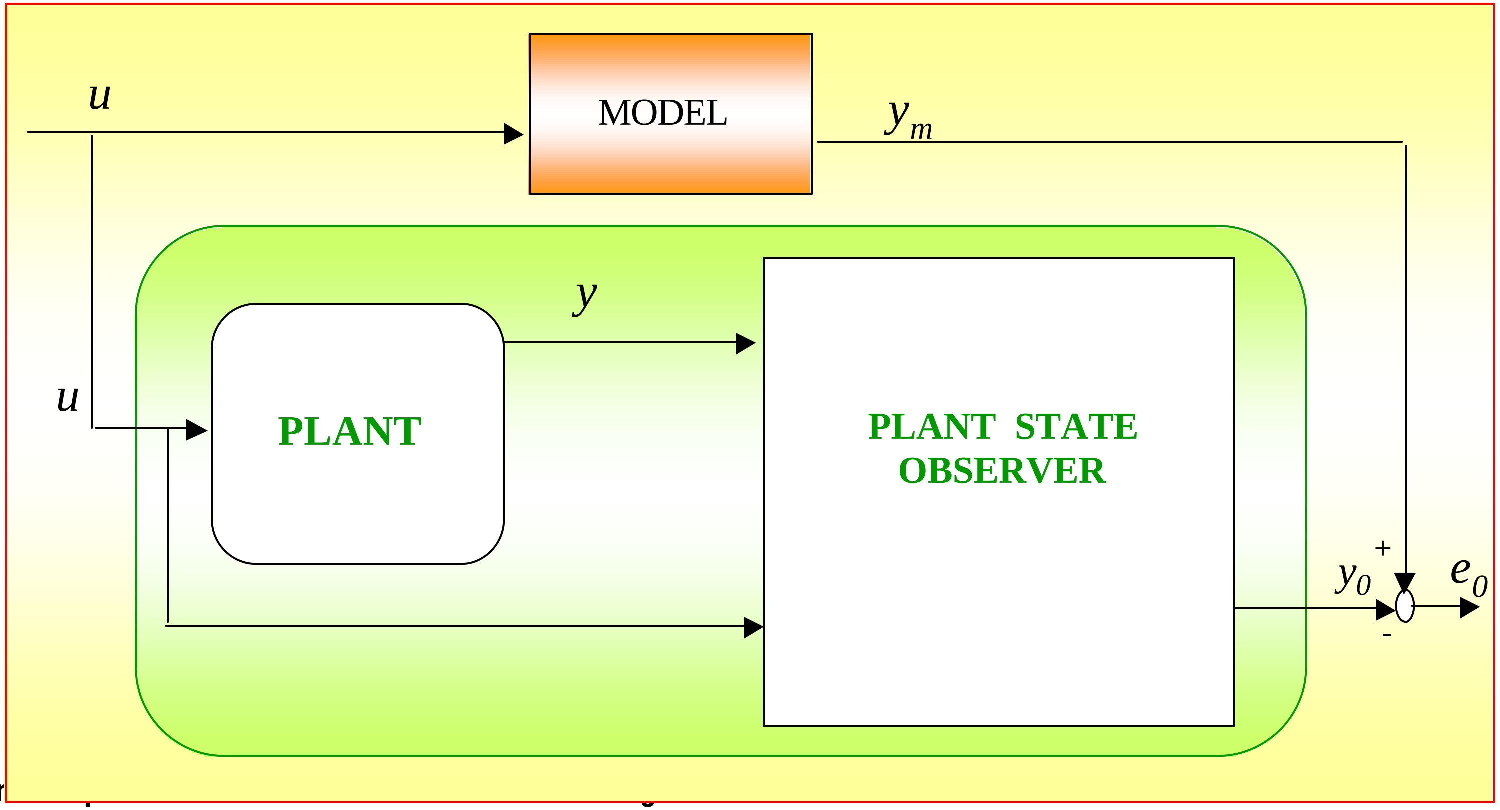
Where $||e|| < Q^*||r|| \ \forall r \in R$

THEORETICAL FUNDAMENTALS

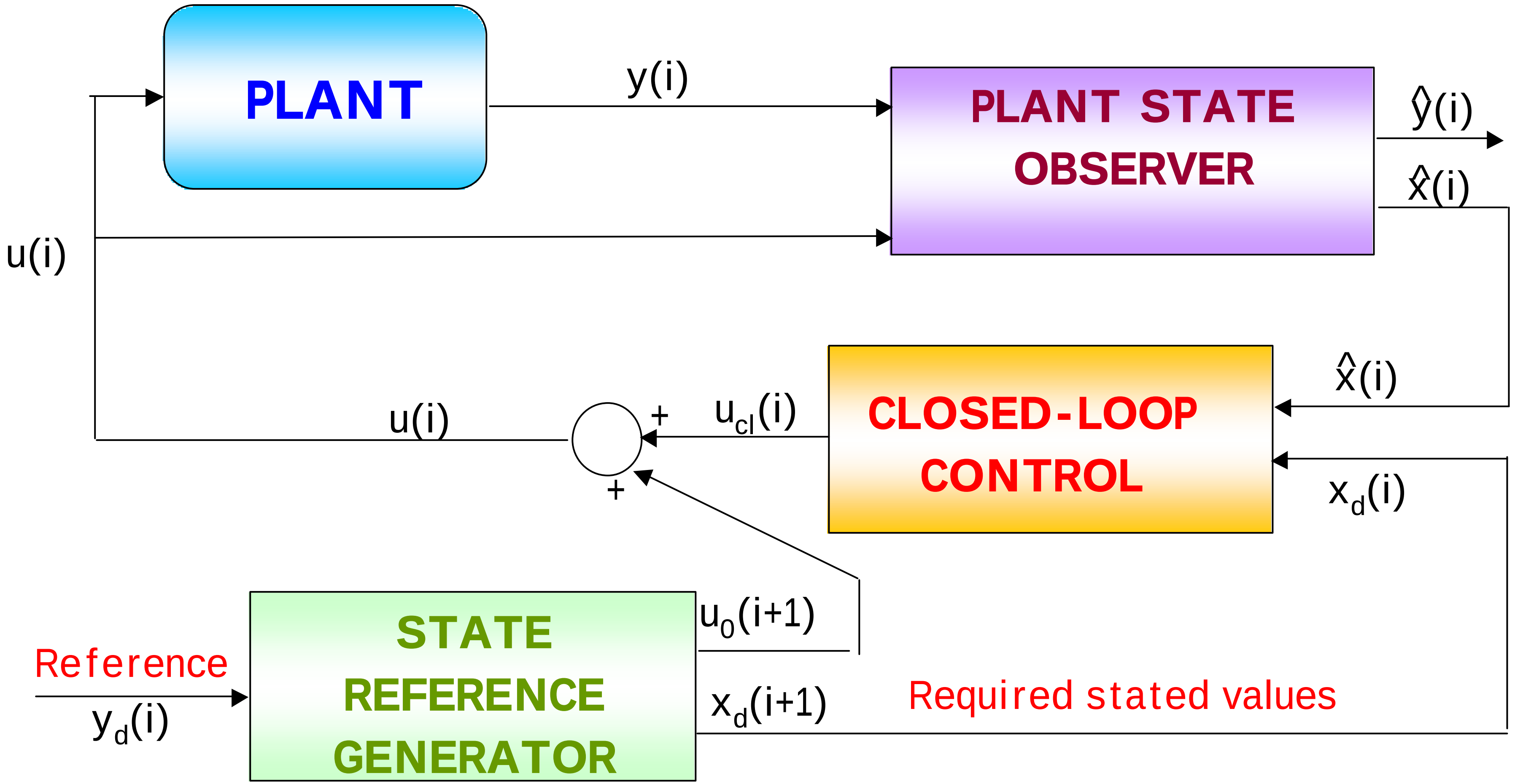
THE FUNDAMENTAL THEOREM

When the uncertainty is evaluated in the whole output Banach space, it appears impossible to build models of physical plants within the constraint *E<1*

but it is possible to satisfy the above condition when <u>bounded frequency domains are considered</u>



THE EICAS CONTROL DESIGN APPROACH



REMARK – THE GUARANTEED PERFORMANCE IS RELATED TO

$$|| x_d(i) - \hat{x}(i) ||$$

THE EICAS CONTROL DESIGN APPROACH

THE GUARANTEED PERFORMANCE IS RELATED TO THE STATE CONTROL

closed loop error $\| x_d(i) - \hat{x}(i) \|$ **<** $Q^* \| x_d(i) - \hat{x}_o(i) \|$ **open loop error**

The plant control error $\| y_d(i) - y(i) \|$ is the resulting effect of two error causes:

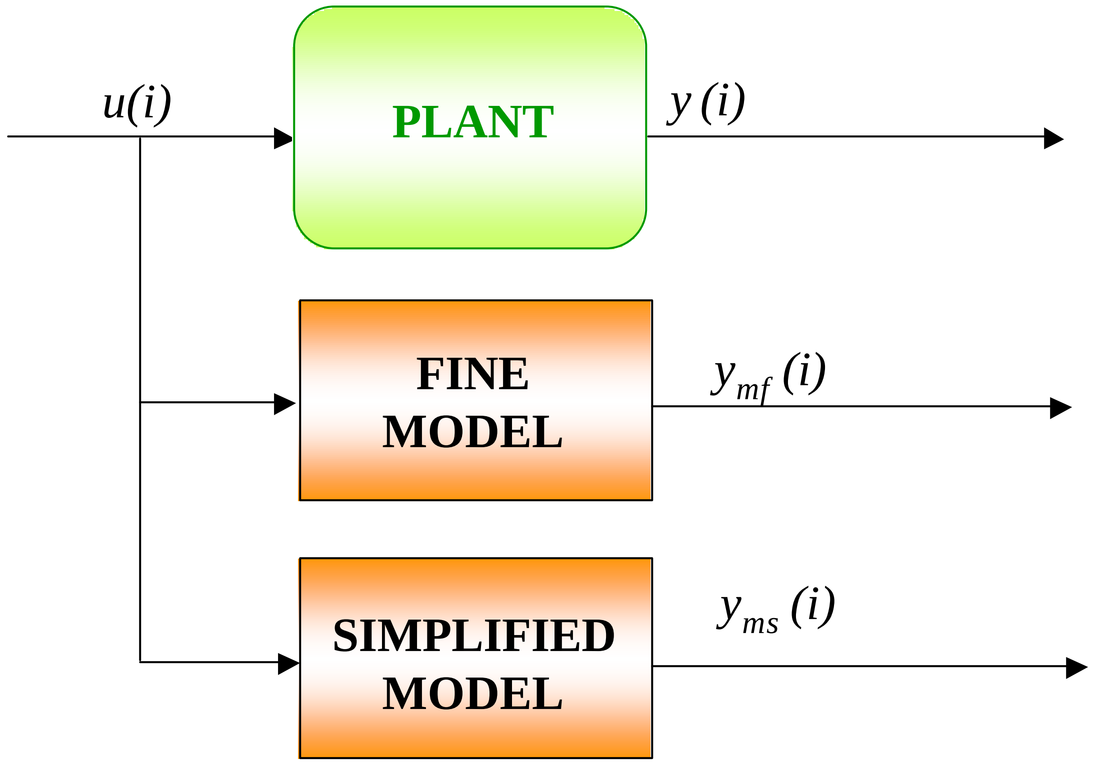
- The control error $\| y_d(i) - y(i) \|$, of the observed output, which can be made so small as required
- the observer error $\| y(i) - y(i) \|$, which depends on the observer design but cannot be made as small as required

CONCLUSIONS:

- the plant control error is “practically” given by the observer error alone
- the observer design is the most critical point in the plant control design

PLANT-MODEL UNCERTAINTY ASSESSEMENT

THE TWO MODELS APPROACH



PLANT CONTROL DESIGN

two different models of the plant are used to design the plant control algorithm.

The “plant simplified model” is the main basis of the control design.

The “plant fine model” is strictly related to the previous one, having the aim of showing the limit of the field within which the “plant simplified model” gives a description of the plant behavior sufficiently accurate from the point of view of the control design.

PLANT CONTROL DESIGN

The plant control design consists of two main steps: the state observer design and the state controller design.

The state controller design is performed only on the basis of the "plant simplified model" with the aim of getting any stated attenuation factor Q_o

The state observer design is also performed on the basis of the "plant simplified model", but with requirements derived from the "plant fine model" analysis.

PLANT CONTROL DESIGN

The **control guaranteed performance** is evaluated by a set of trials performed in a simulated environment by applying the designed control to the “plant fine model”.

In order to **optimize** the control performance a tuning of the control parameters can also be performed in the same environment simulated above.

THE CONTROL DESIGN APPROACH

1. "REQUIREMENT SPECIFICATIONS"
2. PLANT SIMPLIFIED MODEL
3. PLANT FINE MODEL
4. ACCURACY LIMIT VERIFICATION (E<1)
5. CONTROL DESIGN

THE ACODUASIS EXPERIENCE

The experience has proved that:

- plant controls designed according to the described methodology do not need experimental parameter tuning in field
- the control performance obtained by sophisticated modern controls is better than the one obtained by means of simple controls experimentally tuned.

FROM THE ACODUASIS EXPERIENCE

The most critical step in the plant control design is the choice of the plant simplified model and of the related plant fine model.

Such a model selection requires deep expertise in designing controls for the specific technological sector considered.

Once the two models have been selected, the following control design steps can be largely automated and supported by a professional software tool like EICASLAB