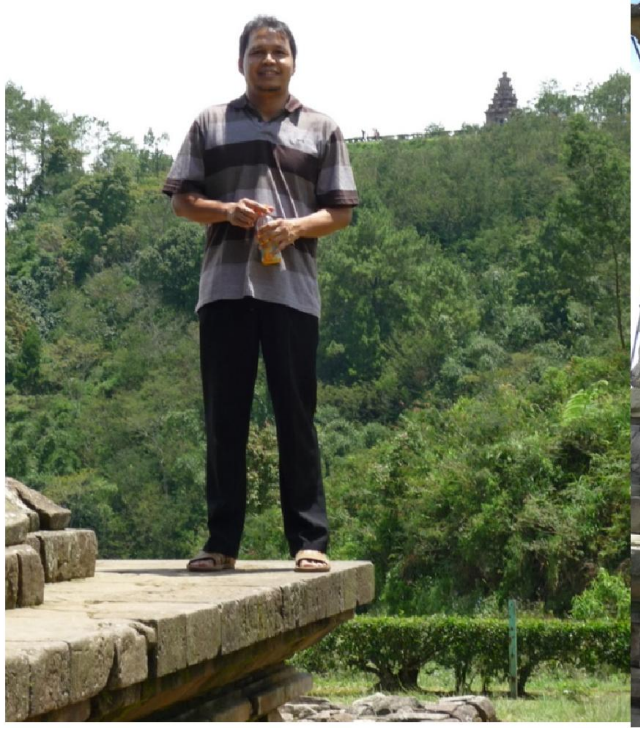
# Meeting you, Djaeni and Cindy

## @ Diponegoro University



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## Mathematical model

- The mathematical model consists of (first-order) *differential equations* recognisable by presence of *rates of change* dx/dt.
- Models containing differential equations are called *dynamic* models.
- Dynamic models are obtained from *knowledge* of the system, often *scientific knowledge* (first-principles models / white box models).
- Using scientific knowledge allows us to *understand and interpret* the model!
- Black box models do not allow for this.

## Summary

- Optimal control problem: *Given* a mathematical dynamic model of the system *find* the control patterns (time-functions/trajectories/histories) that *maximize* (minimize) a *cost function* (performance measure/cost criterion/penalty function).
- Problem formulation is still missing one thing ...
- We also have to know "where the system starts"
- We have to know the *initial state* : values of W(0), T(0), $CO_2$(0).

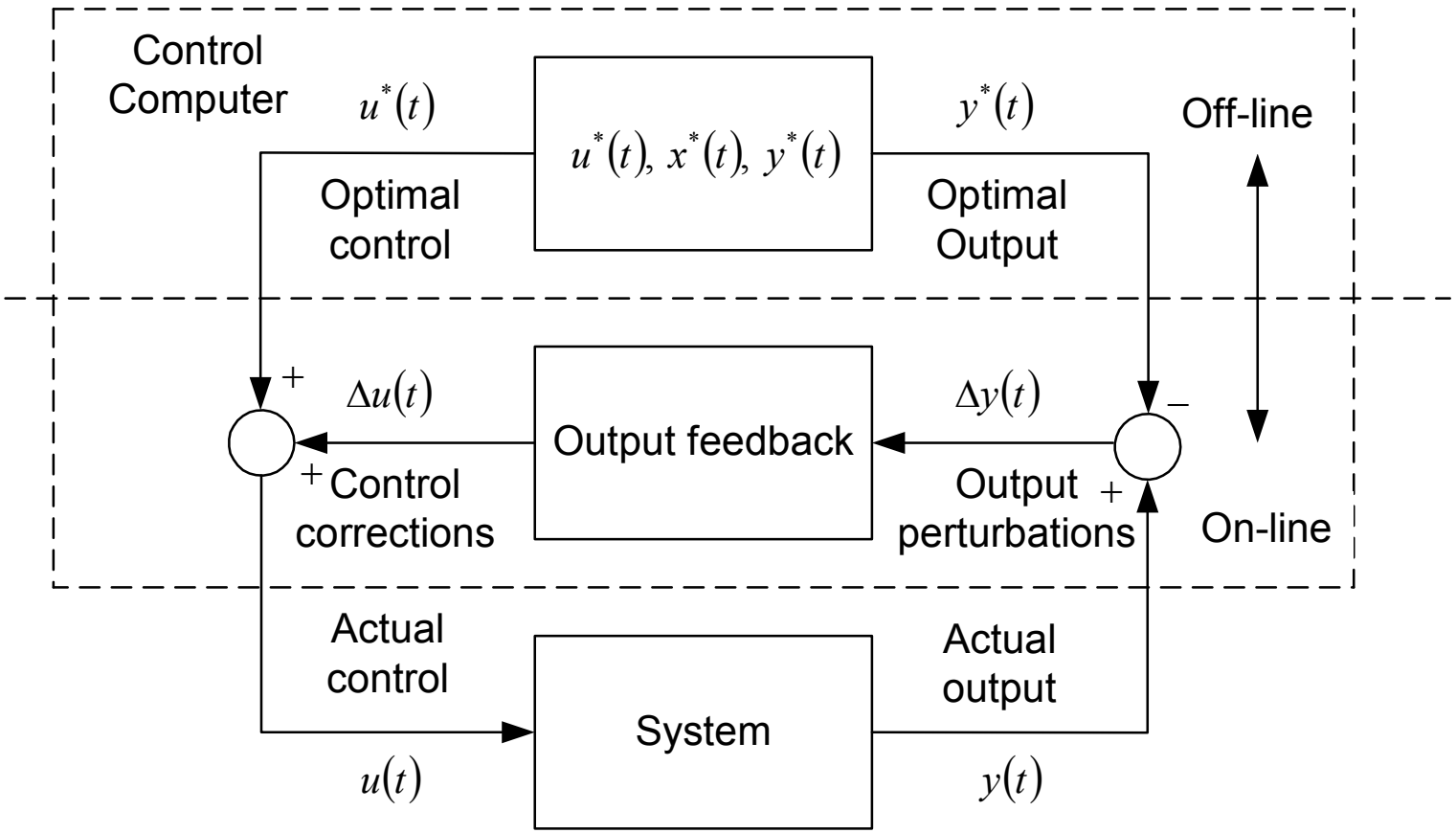
## Summary (1)

- With optimal control:
  - *All* types of systems can be handled.
  - *All* types of control objectives can be considered.
  - *All* types of constraints can be handled.
- This requires:
  - A quantitative mathematical dynamic model of the system obtained by exploiting scientific knowledge.
  - A quantitative mathematical description of the control objectives.
  - A quantitative mathematical description of the constraints.
- What you get: The *best* control & performance!

## Summary (2)

- Measurements:
  - are *only* required to realize feedback to counteract model and other types of *uncertainty.*

# Optimal Control System



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## State space models, simulation and steady states

- Learn how to obtain a state-space model systematically
- Use state-space models do perform simulations
- Steady state computation: Simple control problem
- Continuation lecture on black board



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## Summary (1)

- We learned how to obtain a state-space model systematically
  - Make sketch/drawing with mathematical symbols
  - From (mass/energy/..) balance equations obtain differential equations (use of scientific knowledge)
  - 1) Find states x (those variables showing time derivatives)
  - 2) Find parameters p (all constants)
  - 3) Find inputs u (variables that remain)
  - From this obtain dx/dt=f(x,u,p)
  - 4) Find outputs y (measured variables/variables of interest)
  - From this obtain y=g(x,u,p)

## Summary (2)

- Using it on a computer we can perform simulations:
  - From the input trajectories (time functions) we calculate the state response (state trajectories = system behaviour) and the output response (output trajectories)
  - Simulations are needed to compute optimal controls
- Steady state computation: Simple control problem
  - Compute controls to keep states constant
  - Do small deviations from steady state tend to zero? If yes steady state stable, otherwise not
  - Check this by computing eigenvalues of $\left.\frac{\partial f}{\partial x}\right|_{\substack{x=x^{ss}\\u=u^{ss}}}$
  - Properties of $f, x^{ss}, u^{ss}$ determine this