SE View of a Kalman Filter

Systems Engineering
View of a Kalman Filter

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Systems Engineering View of a Kalman Filter

Overview of Presentation

- Why use a Kalman Filter?
- What is the structure of a Kalman Filter?
- How can we quantify the "Kalman Gain"?

Simple example of measuring a Dynamic System

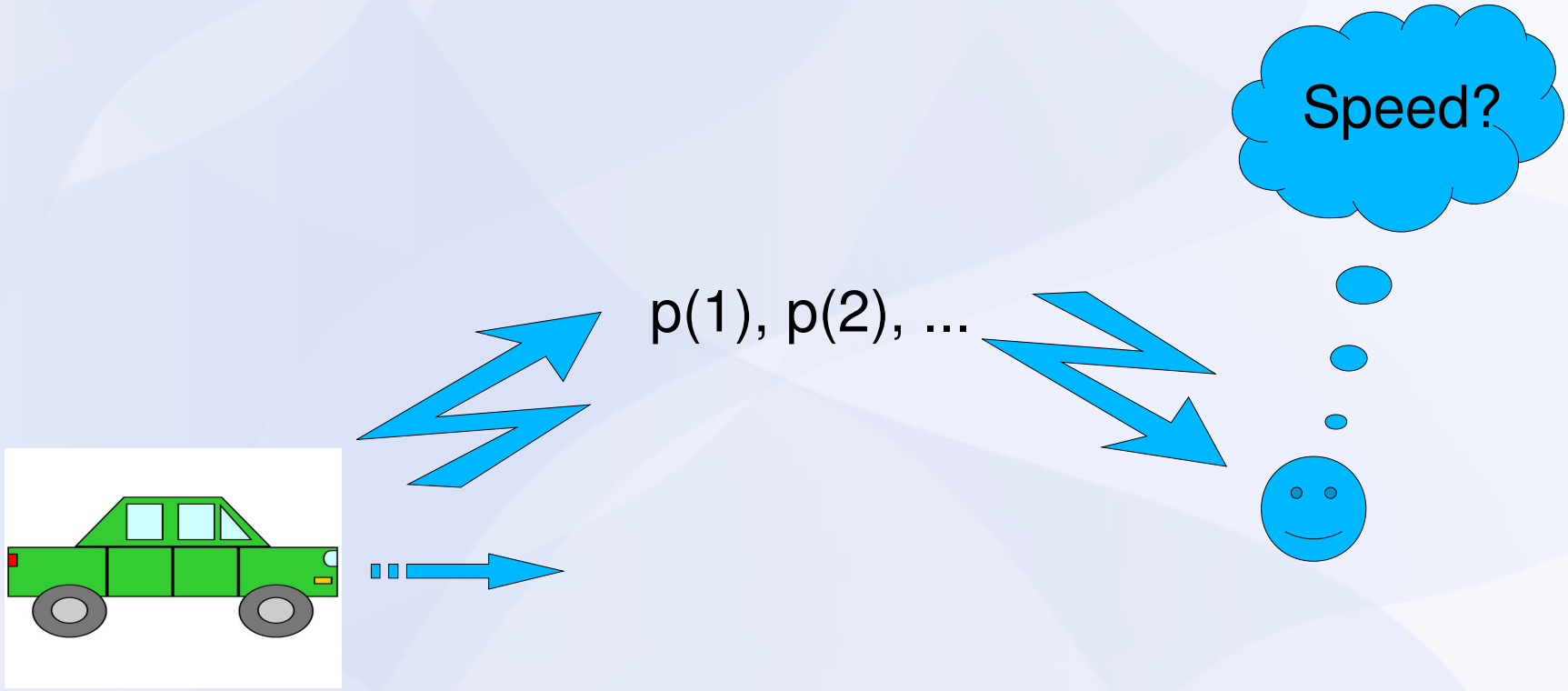


Diagram 1

Another Simple example of measuring a Dynamic System

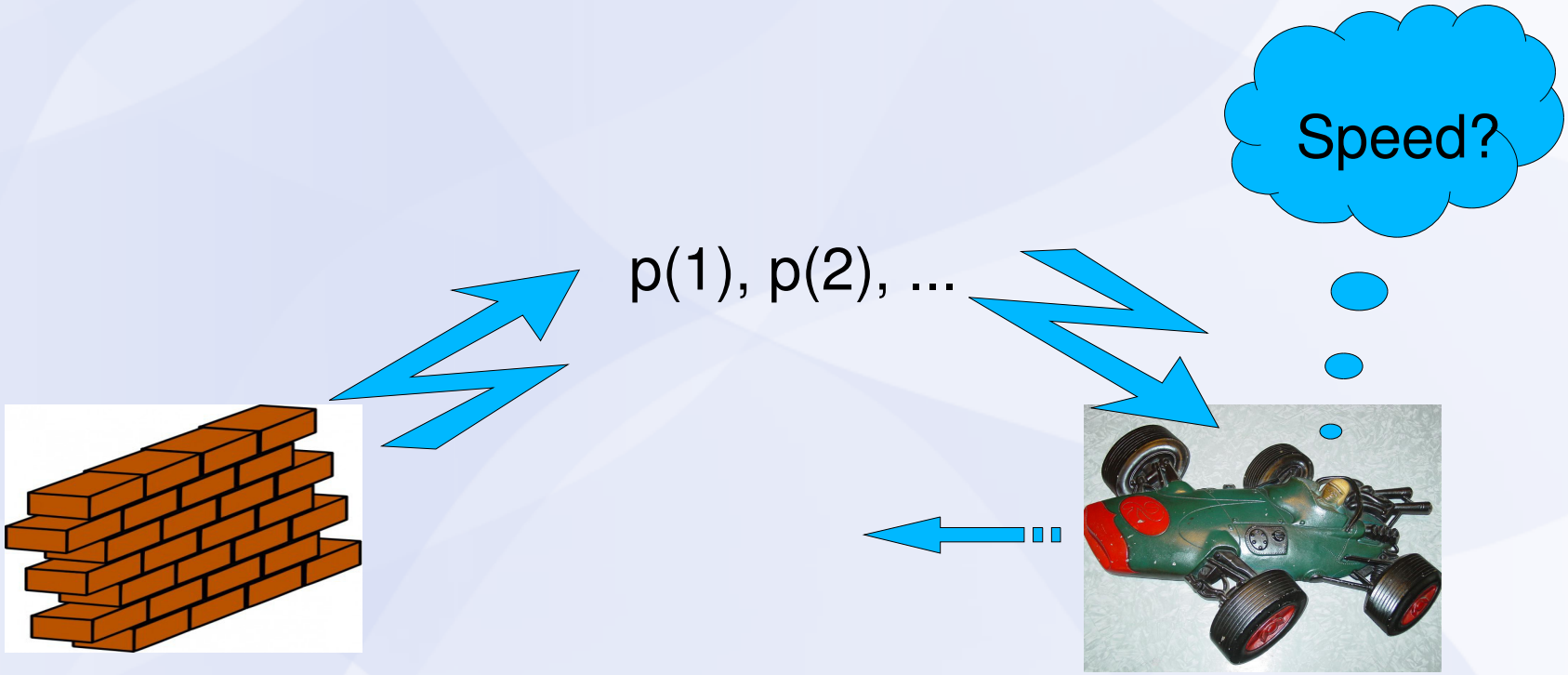


Diagram 2

Discrete Equations for Dynamics of a One Dimension System

$$p(k+1) = p(k) + s(k)*T + c(k)*T^2/2$$
$$s(k+1) = s(k) + c(k)*T$$

where,

p = position, s = speed, c = (known) acceleration,
T = time interval of updates, k = update number

Diagram 3

Discrete State Space Equation of a (Linear) Dynamic System

$$x(k+1) = A*x(k) + B*u(k)$$

where,

x = the state of the system

with 2 components x_1 = p and x_2 = s

and u = c.

Diagram 4

State Space View of a (Linear) Dynamic System

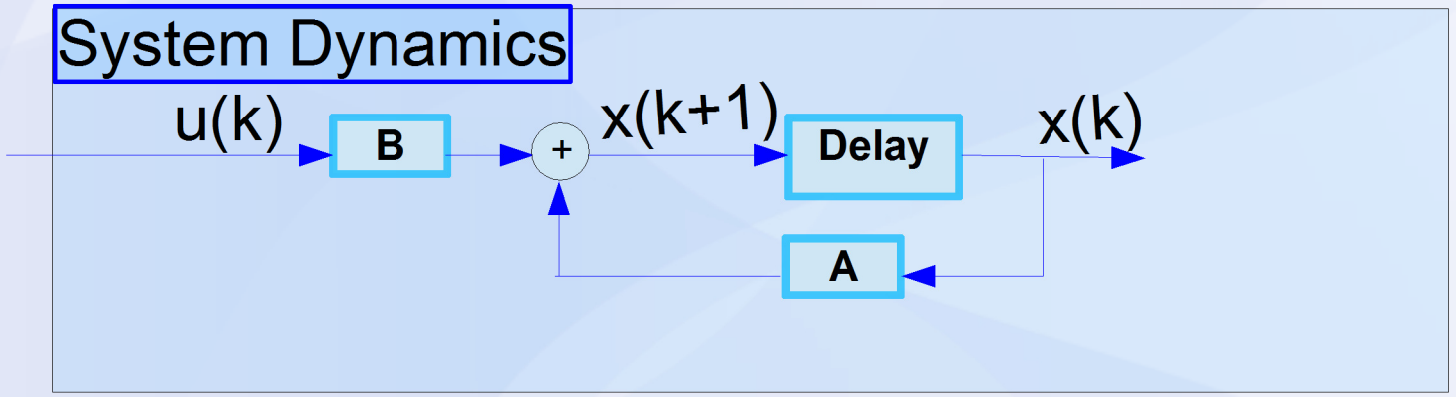
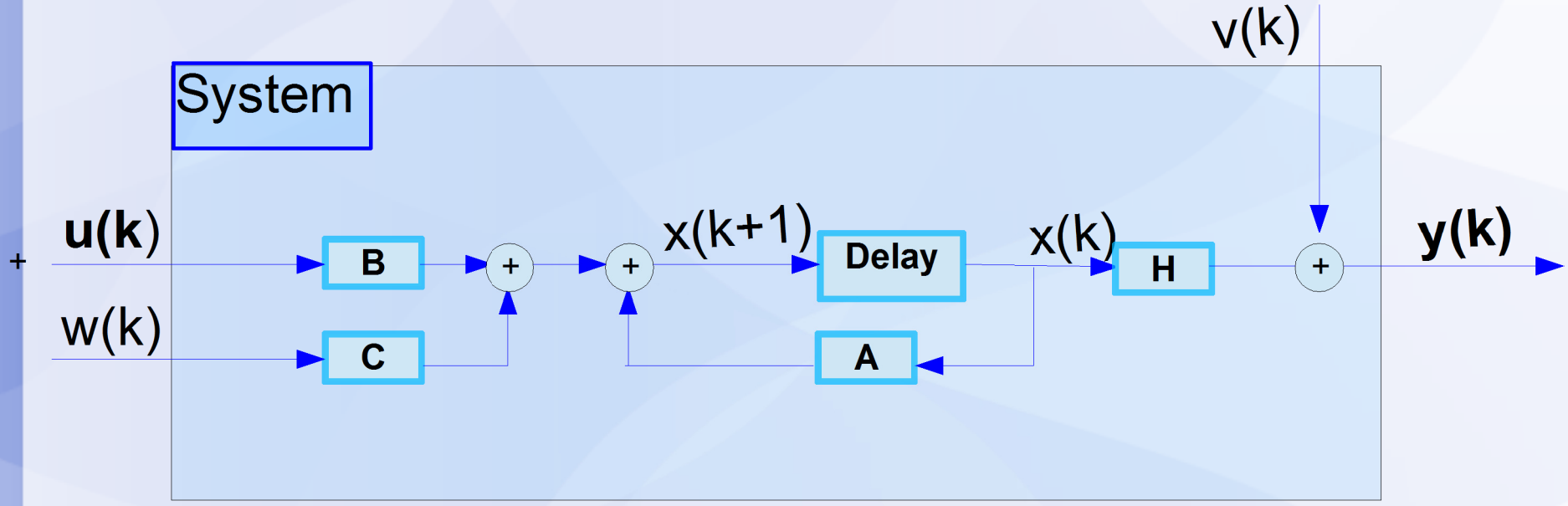


Diagram 5

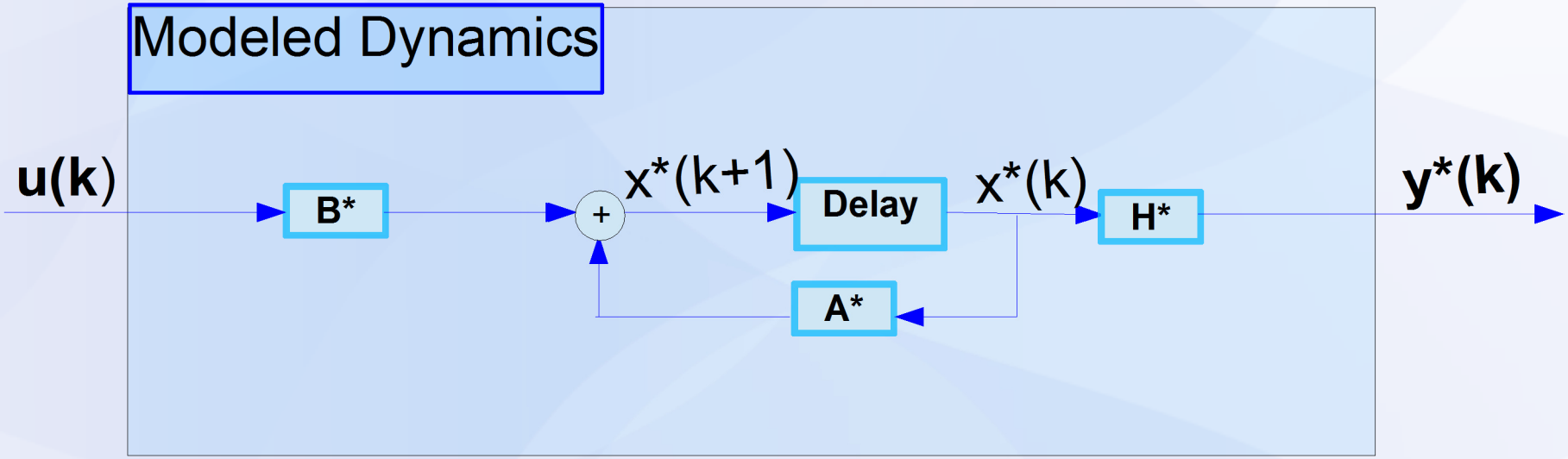
State Space View of a (Linear) Dynamical System



Generally we cannot see the state, x(k), directly. We see only y(k), a transformation of the state, H*x(k), and that is contaminated (by noise, v(k)).

Diagram 6

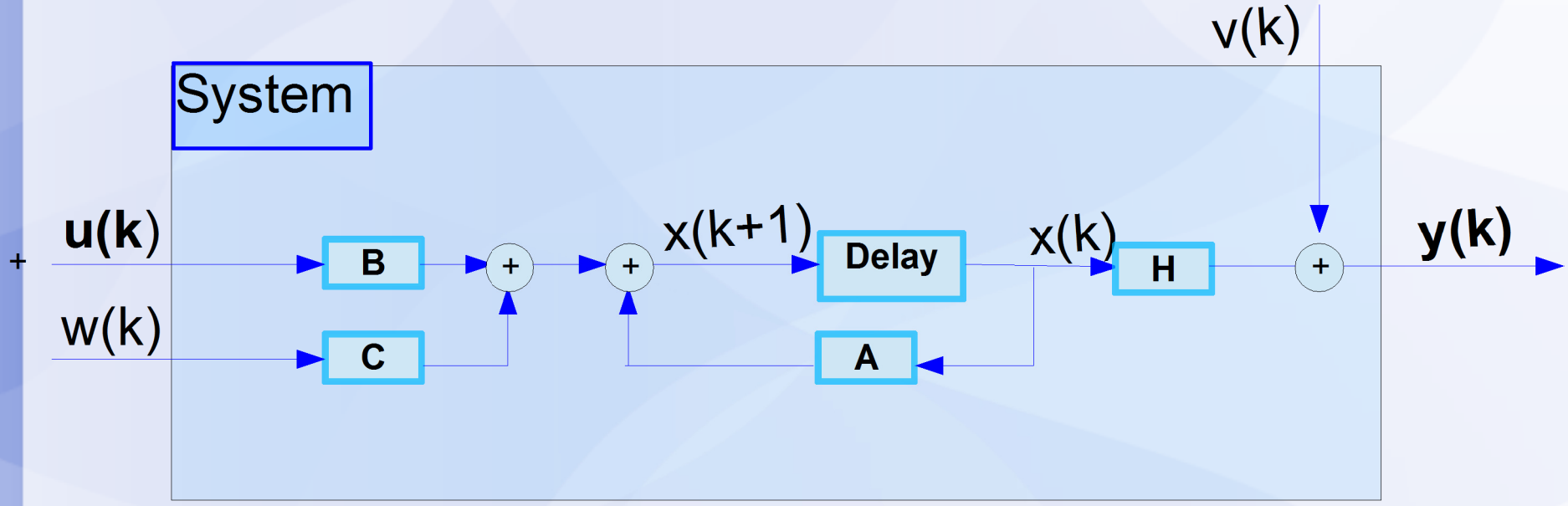
State Space Model of a (Linear) Dynamical System



Perfect knowledge of the Dynamics (A, and B) with known initial conditions (x*(0) = x(0)) would allow perfect future state prediction from u(k).

Diagram 7 – Questions?

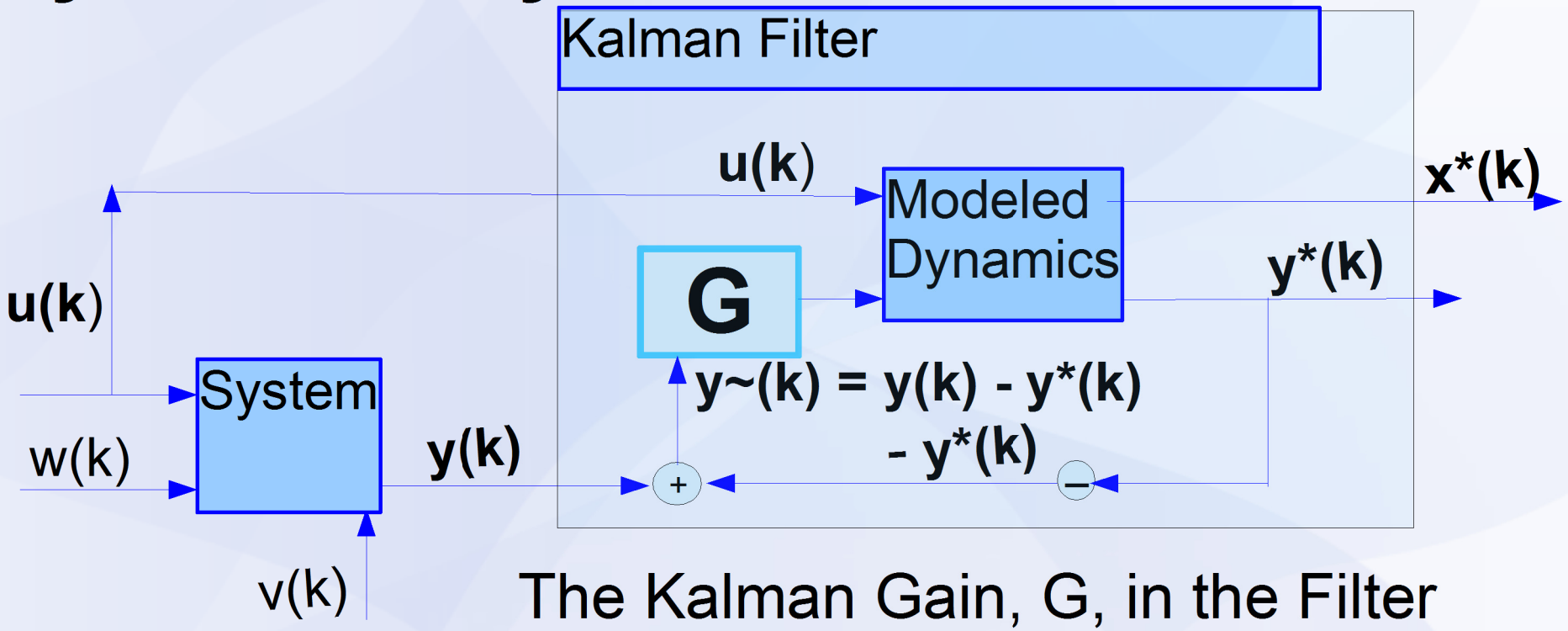
State Space View of a (Linear) Dynamical System



There are three inputs to the system, (w, v, and u) only one of which is known, u(k).

Diagram 6 (again)

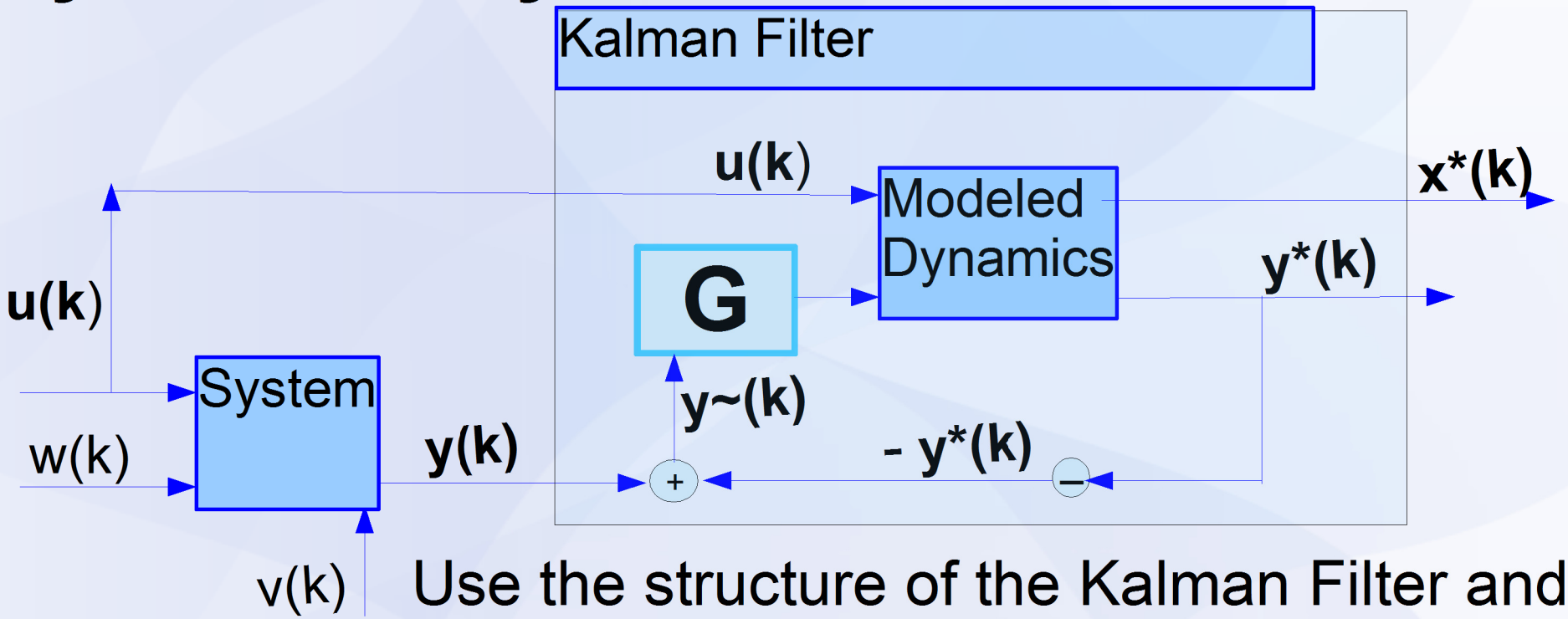
State Space View of a Dynamical System and Kalman Filter



The Kalman Gain, G, in the Filter corrects the Estimated State, x*.

Diagram 8 – Questions?

State Space View of a Dynamical System and Kalman Filter



Use the structure of the Kalman Filter and Innovative ways of Determining G to correct the Estimated State, x*.

Diagram 8 (again)

Selecting Parameters in G

- What we want to do is to correct the inputs to the system model based on the errors between:
  - the measurements of the system and
  - the measurement estimates from the model.
- First, apply logic of the sign of the corrections.
  - E.g., if the position measurement of the model is behind the measurement of the system, we need to apply some increase in the acceleration and speed in the model.
  - So how can we elaborate on this idea?
    - We can do it manually, guessing at values and tweaking them in simulations.
    - But, why not automate that?

More of Selecting Parameters in G

- How about using genetic algorithms on simulation data to determine the correct values of the elements in the G?
- How about using a neural net on the data to determine the static values of the elements in the Kalman Gain?
- How about using a neural net to (within bounds) change the values of the elements in the Kalman Gain in real time?

There are other ad hoc methods you may explore for obtaining the values of the parameters in the Kalman Gain when you intuitively understand the basic structure of a (dynamic) Kalman Filter, aren't there?

Systems Engineering View of a Kalman Filter

Summary of Presentation

- Why use a Kalman Filter?
  - Uses knowledge of system dynamics to provide improved estimation of the system state.
- What is the structure of a Kalman Filter?
  - Contains a dynamic model of observed system.
  - Uses error in prediction of measurement to correct prediction of state estimation.
- How can we quantify the Kalman Gain?
  - Formal computation from the theory.
  - Ad hoc methods such as pre-computation from theory or from neural networks.