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This Week's Citation Classic

Luenberger D G. Observers for multivariable systems. *IEEE Trans. Automat. Contr.* **AC-11:190-7, 1966.** [Dept. Electrical Engineering, **Stanford Univ., Stanford, CA]**

A dynamic system is characterized at any moment by its state variables—velocities, positions, temperatures, etc. Often many of these cannot be directly measured, although knowledge of their values might be very useful. An observer constructs estimates of the variables that cannot be measured, using only the variables that can be measured. [The *SCI*® indicates that this paper has been cited over 225 times since 1966.]

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"In the late 1950s and early 1960s the field of control theory and dynamic systems experienced a revolutionary change with the introduction of state space methods. In this framework a dynamic system is represented by a set of first-order differential equations expressed in terms of a number of state variables. The values of the state variables at any time provide a logical and complete basis for determining the best control at that time. This feature led to a whole new assortment of important control strategies based on the state variables. These new methods were developed mainly in the context of aerospace systems, which typically could be accurately described using Newtonian mechanics with six state variables, ail of which could be measured.

"In the early 1960s, I was a Stanford graduate student on an internship at Westinghouse Research Laboratories, and part of a small group that sought to apply these modern state space methods to the control of large industrial problems —especially to the control of an electric power plant. Such systems possessed a very large number of state variables but only relatively few of these were available for measurement. In order to use the modern state space methods, it was imperative that all state variables be available. This led to the problem of trying to construct estimates of those that were not available from those that were. The resulting solution was surprisingly simple and flexible. It took the form of another dynamic system whose inputs were the available measurements of the original system. The state of this 'observer' produced good estimates of the state variables of the original system, and these estimates could be used, as if they were true measurements, to compute the appropriate control.

"The work formed the basis for my PhD dissertation and was originally published for the case of a single measurement.[1] The later 1966 paper, cited more frequently, considers the more general case. More recently I published 'An introduction to observers.'[2] I believe that the 1966 paper has been cited frequently for two basic reasons. First, it does solve a wide class of practical problems. Indeed, observers have been used as a component of control systems in many applications, including servo mechanisms, space systems, industrial processes, aircraft, and even complex economic systems. Second, observers seem to have a great theoretical fascination. Their theory encompasses many of the fundamental components of state space theory, including controllability, observability, eigenvalue analysis, feedback, canonical forms, and decomposition. For this reason observers have arisen naturally in the consideration of many of these other topics. I like to think that the success of this work was due to the happenstance of simultaneous involvement in a real practical problem and being exposed to a relevant emerging new theoretical area."

1. **Luenberger D G.** Observing the stale of a linear system. *IEEE Trans. Mil. Electron.* **MIL-8.**74-80, 1964.
[The *SCI*® indicates that this paper has been cited over 170 times since 1964.]
2............................. An introduction to observers. *IEEE Trans . Automat. Contr.* AC-16:596-602. 1971.