Short Note on Open-Loop and Closed-Loop Systems to add Conceptual Clarification

In control engineering, the terms open-loop and closed-loop arise when we discuss the architecture adopted to control the output of a plant.

An open-loop control system is one in which the control action does not depend on the output of the system. The controller generates an input purely based on the reference or command signal, without observing whether the desired outcome has actually been achieved. For example, consider a DC motor driven by a fixed voltage to achieve a certain speed. If the voltage is applied without measuring the motor speed and without adjusting the input based on the actual speed, the system is open-loop. Any disturbance such as load variation, friction change, or supply fluctuation will affect the output, but the controller will remain unaware of it.

A key point that often causes confusion is that a system may internally contain feedback mechanisms and still be treated as open-loop from a control perspective. For instance, a DC motor has back electromotive force (back-EMF), which is a form of internal feedback linking speed to armature voltage. Yet, when we design a controller that simply applies a voltage without measuring speed, we still call the system open-loop. This is because the designed controller does not use output information. Internal physical feedback is part of the plant dynamics, not a deliberate control strategy.

In contrast, a closed-loop control system is one in which the controller explicitly uses feedback from the output to compute the control action. The output is measured, compared with the reference, and the resulting error drives the controller. A speed-controlled DC motor using a tachometer or encoder is a typical example. If the speed drops due to an increased load, the controller detects the error and increases the armature voltage to compensate. The defining feature here is intentional feedback used by the controller to reduce error and improve performance.

An important conceptual refinement is that a closed-loop system can itself be viewed as an open-loop system from a higher-level perspective. Once a controller and plant are connected in feedback, the resulting closed-loop behaves as a single input–output system mapping the reference to the output. From this viewpoint, the internal feedback loop is hidden, and the overall system can be treated as an equivalent open-loop block for purposes such as performance analysis, system interconnection, or hierarchical control design. For example, in cascade control, the inner loop may be closed-loop, while the outer loop treats it as a new "plant."

Similarly, whether a system is open-loop or closed-loop depends on the signal of interest. A system may be closed-loop with respect to disturbance rejection but open-loop with respect to reference tracking, or vice versa. Thus, open-loop and closed-loop are not absolute labels but context-dependent descriptions.

In summary, an open-loop system is one where the controller does not use output information, even if the plant itself has internal feedback. A closed-loop system is one where feedback is deliberately used in the controller design. Moreover, a closed-loop system can often be treated as an open-loop system at a higher level of abstraction. As complex engineering systems often consist of nested control loops, a closed-loop control system with respect to one input–output pair can be viewed as an open-loop system with respect to another input–output pair. Understanding these distinctions helps move beyond block-diagram formalism and toward a deeper engineering intuition about control system design.