Servomechanism

A **servomechanism**, sometimes shortened to **servo**, is an automatic device that uses error-sensing negative feedback to correct the performance of a mechanism.

The term correctly applies only to systems where the feedback or error-correction signals help control mechanical position, speed or other parameters. For example, an automotive power window control is not a servomechanism, as there is no automatic feedback that controls position—the operator does this by observation. By contrast the car's cruise control uses closed loop feedback, which classifies it as a servomechanism.

Industrial servomotor
The grey/green cylinder is the brush-type DC motor. The black section at the bottom contains the planetary reduction gear, and the black object on top of the motor is the optical rotary encoder for position feedback. This is the steering actuator of a large robot vehicle.

Uses

Position control

A common type of servo provides *position control*. Servos are commonly electrical or partially electronic in nature, using an electric motor as the primary means of creating mechanical force. Other types of servos use hydraulics, pneumatics, or magnetic principles. Servos operate on the principle of negative feedback, where the control input is compared to the actual position of the mechanical system as measured by some sort of transducer at the output. Any difference between the actual and wanted values (an "error signal") is amplified (and converted) and used to drive the system in the direction necessary to reduce or eliminate the error. This procedure is one widely used application of control theory.

Speed control

Speed control via a governor is another type of servomechanism. The steam engine uses mechanical governors; another early application was to govern the speed of water wheels. Prior to World War II the constant speed propeller was developed to control engine speed for maneuvering aircraft. Fuel controls for gas turbine engines employ either hydromechanical or electronic governing.

Other

Positioning servomechanisms were first used in military fire-control and marine navigation equipment. Today servomechanisms are used in automatic machine tools, satellite-tracking antennas, remote control airplanes, automatic navigation systems on boats and planes, and antiaircraft-gun control systems. Other examples are fly-by-wire systems in aircraft which use servos to actuate the aircraft's control surfaces, and radio-controlled models which use RC servos for the same purpose. Many autofocus cameras also use a servomechanism to accurately move the lens, and thus adjust the focus. A modern hard disk drive has a magnetic servo system with sub-micrometre positioning accuracy. In industrial machines, servos are used to perform complex motion.

Rotary or linear

Typical servos give a rotary (angular) output. Linear types are common as well, using a leadscrew or a linear motor to give linear motion.

Servomotor

A *servomotor* is a motor which forms part of a servomechanism. The servomotor is paired with some type of encoder to provide position/speed feedback. A stepper motor is one type of servomotor. A stepper motor is actually built to move angular positions based upon each possible step around the entire rotation, and may include microsteps with a resolution such as 256 microsteps per step of the stepper motor. A servomechanism may or may not use a servomotor. For example, a household furnace controlled by a thermostat is a servomechanism, because of the feedback and resulting error signal, yet there is no motor being controlled directly by the servomechanism.

History

James Watt's steam engine governor is generally considered the first powered feedback system. The windmill fantail is an earlier example of automatic control, but since it does not have an amplifier or gain, it is not usually considered a servomechanism.

The first feedback position control device was the ship steering engine, used to position the rudder of large ships based on the position of the ship's wheel. This technology was first used on the SS Great Eastern in 1866. Steam steering engines had the characteristics of a modern servomechanism: an input, an output, an error signal, and a means for amplifying the error signal used for negative feedback to drive the error towards zero. The Ragonnet power reverse mechanism was a general purpose air or steam-powered servo amplifier for linear motion patented in 1909.[1]

Electrical servomechanisms were used as early as 1888 in Elisha Gray's Telautograph.

Electrical servomechanisms require a power amplifier. World War II saw the development of electrical fire-control servomechanisms, using an amplidyne as the power amplifier. Vacuum tube amplifiers were used in the UNISERVO tape drive for the UNIVAC I computer. The Royal Navy began experimenting with Remote Power Control (RPC) on HMS Champion in 1928 and began using RPC to control searchlights in the early 1930s. During WW2 RPC was used to control gun mounts and gun directors.

Modern servomechanisms use solid state power amplifiers, usually built from MOSFET or thyristor devices. Small servos may use power transistors.

The origin of the word is believed to come from the French "*Le Servomoteur*" or the slavemotor, first used by J. J. L. Farcot in 1868 to describe hydraulic and steam engines for use in ship steering.[2]

The simplest kind of servos use bang–bang control. More complex control systems use proportional control, PID control, and state space control, which are studied in modern control theory.

RC servos

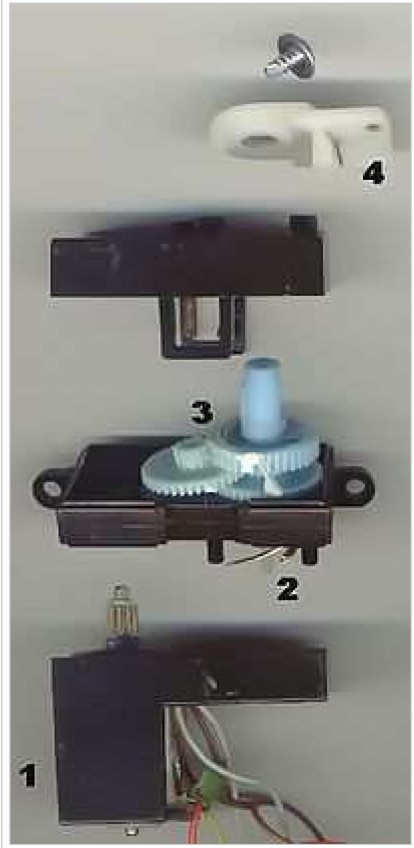
RC servos are hobbyist remote control devices servos typically employed in radio-controlled models, where they are used to provide actuation for various mechanical systems such as the steering of a car, the control surfaces on a plane, or the rudder of a boat.

Due to their affordability, reliability, and simplicity of control by microprocessors, RC servos are often used in small-scale robotics applications.

RC servos are composed of an electric motor mechanically linked to a potentiometer. A standard RC receiver sends pulse-width modulation (PWM) signals to the servo. The electronics inside the servo translate the width of the pulse into a position. When the servo is commanded to rotate, the motor is powered until the potentiometer reaches the value corresponding to the commanded position.

RC servos use a three-pin 0.1" spacing jack (female) which mates to standard 0.025" square pins. The most common order is signal, +voltage, ground. The standard voltage is 4.8 V DC, however 6 V and 12 V has also been seen for a few servos. The control signal is a digital PWM signal with a 50 Hz frame rate. Within each 20 ms timeframe, an active-high digital pulse controls the position. The pulse nominally ranges from 1.0 ms to 2.0 ms with 1.5 ms always being center of range. Pulse widths outside this range can be used for "overtravel" -moving the servo beyond its normal range. This PWM signal is sometimes (incorrectly) called Pulse Position Modulation (PPM).

The servo is controlled by three wires: ground, power, and control. The servo will move based on the pulses sent over the control wire, which set the angle of the actuator arm. The servo expects a pulse every 20 ms in order to gain correct information about the angle. The width of the servo pulse dictates the range of the servo's angular motion.



Small R/C servo mechanism
1. electric motor
2. position feedback potentiometer
3. reduction gear
4. actuator arm

A servo pulse of 1.5 ms width will typically set the servo to its "neutral" position or 45°, a pulse of 1.25 ms could set it to 0° and a pulse of 1.75 ms to 90°. The physical limits and timings of the servo hardware varies between brands and models, but a general servo's angular motion will travel somewhere in the range of 90° - 120° and the neutral position is almost always at 1.5 ms. This is the "standard pulse servo mode" used by all hobby analog servos.

A hobby digital servo is controlled by the same "standard pulse servo mode" pulses as an analog servo.[3] Some hobby digital servos can be set to another mode that allows a robot controller to read back the actual position of the servo shaft. Some hobby digital servos can optionally be set to another mode and "programmed", so it has the desired PID controller characteristics when it is later driven by a standard RC receiver.[4]

RC servos are usually powered by the receiver which in turn is powered by battery packs or an electronic speed controller (ESC) with an integrated or a separate battery eliminator circuit (BEC). Common battery packs are either NiCd, NiMH or lithium-ion polymer battery (LiPo) type. Voltage ratings vary, but most receivers are operated at 5 V or 6 V.

Types of performances

Servos can be classified by means of their feedback control systems[5]:

- type 0 servos: under steady-state conditions they produce a constant value of the output with a constant error signal;
- type 1 servos: under steady-state conditions they produce a constant value of the output with null error signal, but a constant rate of change of the reference implies a constant error in tracking the reference;
- type 2 servos: under steady-state conditions they produce a constant value of the output with null error signal. A constant rate of change of the reference implies a null error in tracking the reference. A constant rate of acceleration of the reference implies a constant error in tracking the reference.

The servo bandwidth indicates the capability of the servo to follow rapid changes in the commanded input.