FINAL YEAR PROJECT REPORT

(Simulation of Autopilot using Control System in Matlab)

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Abstract

Autopilot is an automatic flight control system that keeps an aircraft in level flight or on a set course. It can be directed by the pilot, or it may be coupled to a radio navigation signal. Autopilot reduces the physical and mental demands on a pilot and increases safety. The common features available on an autopilot are altitude and heading hold.
The simplest systems use gyroscopic attitude indicators and magnetic compasses to control servos connected to the flight control system. The number and location of these servos depends on the complexity of the system. For example, a single-axis autopilot controls the aircraft about the longitudinal axis and a servo actuates the ailerons. A three-axis autopilot controls the aircraft about the longitudinal, lateral, and vertical axes. Three different servos actuate ailerons, elevator, and rudder. More advanced systems often include a vertical speed and/or indicated airspeed hold mode. Advanced autopilot systems are coupled to navigational aids through a flight director. Here we have designed some important auto pilots by using some assumptions and simply following some design rules and procedures of international standards.

Resultantly obtaining stability derivatives and then autopilots with some inputs and output responses in Matlab by the help of block diagrams.

Chapter#01

Introduction

Autopilot is a mechanical, electrical, or hydraulic system used to guide a vehicle without assistance from a human being. An autopilot can refer specifically to aircraft. In the early days of aviation, aircraft required the continuous attention of a pilot in order to fly safely. As aircraft range increased allowing flights of many hours, the constant attention led to serious fatigue. An autopilot is designed to perform some of the tasks of the pilot.

On seventeenth of December 1903 first successful flight of a powered airplane was established. The Wright brothers succeed in their efforts where others had failed to design their airplane to be unstable but controllable. This break with tradition resulted in a more maneuverable and controllable vehicle that was less susceptible to atmospheric gusts. The approach taken by such pioneers as Lilienthal, Pilcher, Chanute, and Langley in the design of their flying machines was to make them inherently stable, leaving the pilot with no other duty than to steer the vehicle. The price paid for this stability was lack of maneuverability and susceptibility to atmospheric disturbances. The lack of stability introduced by the Wright brothers naturally made the pilot's job more difficult and tiring and more than likely speed up the development of the automatic pilot, often called simply an autopilot.

This inherent instability is still prevalent in aircraft of today in the form of the so-called "spiral divergence which causes a slow divergence in heading and bank angle as a result of any small disturbance. The main purpose then of the early autopilots was to stabilize the aircraft and return it to the desired flight attitude after any disturbance.

Such an autopilot was installed in a Glenn H. Curtis flying boat and first tested in late 1912. The autopilot using gyros to sense the deviation of the aircraft from the desired attitude and servo motors to activate the elevators and ailerons this was developed and built by the Sperry Gyroscope Company of New York under the direction of Dr. E. A. Sperry. The apparatus, called the Sperry Airplane Stabilizer, installed in the Curtis flying boat, won prominence on the eighteenth of June 1914. While piloted by Lawrence Sperry, the son of Dr. Sperry, he won a safety prize of 50,000 francs offered by the Aero Club of France for the most stable airplane. This event took place only eleven years after the Wright brothers' historic flight. During this demonstration, while flying close to the ground under automatic control with the pilot ‘Lawrence Sperry’ standing in the cockpit with both hands over his head, the mechanic was standing and walking back and forth on the wing. In spite of the large yawing and rolling moment generated by the mechanic's presence on the wing, the aircraft maintained its original attitude.

After 1915 public information on automatic pilots became nonexistent due to military security and after the First World War there was little effort expended on advancing the state of the art. A break came in 1933 when Wiley. Post insisted on the installation of the first prototype of the Sperry pneumatic-hydraulic Gyro pilot (An automatic pilot incorporating a gyroscope that initiates corrections to control surfaces on aircraft and thus maintains a preset course and altitude) in his aircraft, the "Winnie May," in which he flew around the world in less than eight days. This flight would have been impossible without the aid of this autopilot which allowed Post to doze for short periods while the aircraft flew on under automatic control. This flight aroused new interest in automatic flight especially for the so-called navigational autopilots, and

in 1947 an Air Force C-54 with a Sperry A-12 autopilot with an approach coupler and Bendix throttle control made a completely automatic trans-Atlantic flight including takeoff and landing. During the entire flight the control column was untouched by human hands, with everything controlled from a program stored on punched cards. That control system used for this feat was not by the application of classical feedback control system design techniques.

These early autopilots were primarily designed to maintain the attitude and heading of the aircraft. With the advent of high-performance jet aircraft new problems have arisen. These problems are in addition to the heading instability and are a matter of unsatisfactory dynamic characteristics. In general, it may be said that if the period of oscillation inherent in an aircraft is 10 seconds or more, the pilot can adequately control or damp the oscillation, but if the period is 4 seconds or less, the pilot's reaction time is not short enough; thus, such oscillations should be well damped. The "short period" pitch and "Dutch roll" oscillations inherent in all aircraft fall into the category of a 4-second oscillation.

However, in almost all jet fighter and jet transport aircraft artificial damping must be provided by an automatic system. Probably the first successful application of a Dutch roll damper system was in a quasi-fly-by-wire configuration installed in the YB-49 Northrop flying wing as early as 1948. The resulting systems are referred to as pitch and yaw dampers.

As the aircraft designers tried to obtain more performance from jet fighters, larger and larger engines were installed along with shorter and thinner wings, this trend resulted in significant changes in the moments of inertia of the aircraft which led to catastrophic results for some aircraft. The culprit was "inertial cross-coupling," which had safely been neglected in the past this phenomenon results when the aircraft rolls at high angular velocities. The normal correction is the installation of a larger and/or more effective vertical stabilizer. This requires a major modification of the airframe that is both costly and time consuming. The effects of inertial cross-coupling can be eliminated with a properly designed control system.

Another stability problem that has manifested itself in some jet fighters is the problem of complete loss of longitudinal stability, or *pitch-up,* at high angles of attack. This phenomenon is more suitable to occur when the horizontal stabilizer is placed on top of the vertical stabilizer to improve lateral stability. The same control system can be, used to stabilize ballistic-type missiles, thus eliminating the necessity to add stabilizing surfaces at the back end of the missile.

There are many other problems that face the control engineer, such as the design of approach couplers to provide automatic approaches to landings in bad weather, altitude and Mach hold control systems to improve fuel economy during cruise, compensators to reduce the effects of body bending, and control systems that automatically perform optimally under variations of air speed and altitude. Regardless of its role, a particular control system will in general respond faster and more accurately but with less reliability than a human controller; the control system in general is unable to exercise judgment. The goal of the control system engineer is to optimize the performance of the system to meet the specified design requirements. The first step in the design procedure is the determination of the system purpose and overall system requirements, such as the mission phases and operational requirements. The second step is the determination of the characteristics of the vehicle, control surface actuators, and feedback sensors. The modifications could be in the form of different feedback quantities and/or the addition of some form of dynamic compensation. Ultimate solution could be an efficient Autopilot system.

Not all of the passenger aircraft flying today have an autopilot system. Older and smaller general aviation aircraft especially are still hand-flown, and even small airliners with fewer than twenty seats may also be without an autopilot as they are used on short-duration flights with two pilots. The installation of autopilots in aircraft with more than twenty seats is generally made mandatory by international aviation regulations. There are three levels of control in autopilots for smaller aircraft. A single-axis autopilot controls an aircraft in the roll axis only; such autopilots are also known colloquially as "wing levelers," reflecting their limitations. A two-axis autopilot controls an aircraft in the pitch axis as well as roll, and may be little more than a "wing leveler" with limited pitch oscillation-correcting ability; or it may receive inputs from on-board radio navigation systems to provide true automatic flight guidance once the aircraft has taken off until shortly before landing; or its capabilities may lie somewhere between these two extremes. A three-axis autopilot adds control in the yaw axis and is not required in many small aircraft.