IAAC Graduate Students in Control 2014

Ben-Gurion University, March 31st 2014

(*) Enclosed please find a program.

(*) Each presentation is allocated 15 minutes lecture time, 5 minutes for questions and discussion, and 5 minutes for switching between speakers.

(*) Venue:
Oren Hall, building No. 26, (floor level)
see
http://in.bgu.ac.il/maps/marcus_map.pdf

(*) Transportation: Both bus and train stop at the university gates.

If you plan enter the campus with a car, please coordinate it IN ADVANCE with Ms. Klara Stolovitch,
E-mail: stolovit@ee.bgu.ac.il
Tel: (08) 646 1518.

Looking forward to seeing you all,

Izchak Lewkowicz.

Graduate Students in Control - Annual Meeting
Program

Ben-Gurion University, Oren Hall, Building 26, March 31st

8:30-9:00 Gathering

9:00-9:10 Greetings

9:10-9:35 Michal Shani, Technion (supervisor: Prof. Raphael Linker)

"Trajectory Planning and Guidance of a Robotic Arm for Tree Pruning"

9:35-10:00 Natan Shemer, Technion (supervisor: Prof. Amir Degani)

"Control of SLIP Modelled Robot Using a Simplified Instantaneous Model"

10:00-10:25 Yaron Zimmerman, Technion (supervisor: Prof. Per-Olof Gutman)

"An Innovative Method for Optimization Based, High Order Controller Auto-tuning"

10:25-10:50 Aaron Friedman, Technion (supervisors: Prof. Yaakov Oshman & Dr. Yaacov Cohen)

"Balanced Truncation of System models Augmented with Aliased Wave-number Pairs for Plane Poiseuille Flow State Estimation"

10:50-11:15 Gilad Fursht, Technion (supervisor: Prof. Moshe Idan)

"Nonlinear Control Algorithms for Low-Cost Seeker Head"

11:15-11:35 Break

11:35-12:00 Liran Malachi, Technion (supervisor: Dr. Maxim Kristalny)

"Optimal Control of Bilateral cooperative Teleoperation Systems with delays"

12:00-12:25 Yoni Murin, Ben-Gurion University (supervisor: Dr. Ron Dabora)

"Uncoded Transmission of Correlated Gaussian Sources Over Broadcast Channels with Feedback"

12:25-12:50 Dr. Dmitry Laschov, Tel-Aviv University (Ex-supervisor Prof. Michael Margaliot)

"On Boolean Control Networks with Maximal Topological Entropy"

12:50-13:20 a Guest Talk - Prof. Daniel Alpay, Mathematics, Ben-Gurion University

"(Generalized) Positive Real Systems"

13:20-14:20 Lunch Break

14:20-14:45 Rami Levi, Ben-Gurion University (supervisor: Dr. Shai Arogeti)

"Inertial Centering of High Speed Flexible Rotor Systems Supported by AMBs"

14:45-15:10 Adi Cohen, Technion (supervisor: Prof. Yishar Or)

"Dynamics and Control of Rehabilitative Exoskeleton with Robotic Crutches"

15:10-15:35 Yoram Zarai, Tel-Aviv University (supervisor: Prof. Michael Margaliot)

"Analysis of the Ribosome Flow Model: A Linear-Algebraic Approach"

15:35-16:00 Avriel Herrmann, Technion (supervisor: Prof. Joseph Ben-Asher)

"Flight Control Law Clearance Using Optimal Control Trajectory"

16:00-16:20 Break

16:20-16:45 Ari Berger, Technion (supervisor: Prof. Per-Olof Gutman))

"A New View of Anti-Windup Design for Uncertain Linear Systems in the Frequency Domain"

16:45-17:10 Sergei Basovich, Ben-Gurion University (supervisor: Dr. Shai Arogeti)

"Iterative Output Control of an Active Magnetic Bearing Based Suspension System"

17:10-17:35 Itai Arad, Ben-Gurion University (supervisor: Dr. Shai Arogeti)

"Coordinated Path Following for Autonomous Vehicle"

17:35-18:00 Yuri Osokin, Technion (supervisors: Prof. Nahum Shimkin & Dr. Aharon Bar-Gill)

"Trajectory Planning for Engine Shutdown Emergency in General Aviation Aircraft"

18:00-18:05 Concluding remarks

Trajectory Planning and Guidance of a Robotic Arm for Tree Pruning

Michal Shani, Technion (supervisor Prof. Raphael Linker)

According to data from the Ministry of Agriculture, more than 25workdays in orchards are devoted to selective pruning of the trees. This has led the Agriculture Ministry to fund the development of a human-integrated semi-automatic system for tree pruning. In this system, the human operator selects the pruning points and the pruning operation itself is executed automatically by a robotic arm. The present work focused on planning the trajectory between pruning points and tracking this trajectory via visual servoing.

Measurements were conducted in orchards in order to obtain geometric characteristics of trees. These measurements showed that trees can be approximated as bent cylinders. Accordingly, the development of the control algorithm was based on an algorithm previously developed for straight cylinders. The control algorithm was tested in laboratory conditions using a 6 DOF robotic arm (Denso) controlled in real-time via Quarc driver (Quanser). The tracking performance was evaluated for several geometries: straight cylinder, bent cylinder with constant curvature, and bent cylinder with sudden curvature change, a situation which is typical of trees. Various orientations of the trajectory relative to the plane of curvature were investigated. The experiments showed the ability of the controller to perform the require task.

Student name: Natan Shemer

Affiliations: Technion Autonomous Systems Program

E-mail: natyshemer@gmail.com

Degree: Studying toward M.Sc.

Thesis Supervisor: Assist. Prof. Amir Degani

Title: Control of a SLIP Modeled Robot Using a Simplified Instantaneous Model

Abstract:

The Spring-Loaded Inverted Pendulum (SLIP) is a widely used model to describe human's, animal's, and robot's running motion. The model consists of a point mass attached to a springy massless leg. The dynamics has two phases: flight, which can be described as a ballistic flight, and a stance phase, where ground reaction forces are applied. Previous works have shown that "traditional" control methods have achieved limited results. This is mainly due to the model highly nonlinear and under-actuated nature.

Seyfarth et. al. proposed exploiting the natural dynamics of the model in order to increase robustness to ground height changes. They have suggested an open-loop control scheme that involves swinging the leg backwards at a constant rate starting from apex. This has been shown to increase robustness both numerically and experimentally. The swing leg retraction method has been observed both at animals and human running.

In this work we will present an analytic proof of the increased robustness of the swing-leg retraction method. This will be based on a simplified instantaneous SLIP model (I-SLIP). The analysis provides a way to isolate the optimal parameters of the swing-leg retraction method. We validate these optimal parameters in simulations and proof-of-concept experiments in a planar environment.

Student Name: Yaron Zimmerman

Student affiliations and e-address: yaron.zimmerman@gmail.com

Degree Studying toward (M.Sc./Ph.D.): M.Sc.

Thesis Supervisor: Prof. P-O. Gutman

Title of Talk: **An innovative method for optimization based, high order controller auto-tuning**

Abstract (200 words maximum):

A new automatic method to tune the parameters of high order linear controllers is presented. The auto-tuning is achieved by minimizing, without constraints, a cost function that is related to the open loop shaping problem. The effort demanded from the designer is similar to that required to tune a low order controller such as PI or PID. The capabilities of the new method are demonstrated on two examples.

Balanced Truncation of System Models Augmented with Aliased Wave-Number Pairs for Plane Poiseuille Flow State Estimation

Aaron Friedman, Technion

(supervisors: Prof. Yaakov Oshman & Dr. Yaacov Cohen)

This research addresses the model order reduction of state estimators for plane Poiseuille flow augmented with aliased wave-number pairs, as necessitated by reduced resolution sensing. Balanced truncation is applied to the dynamic models of the augmented subsystems of individual wave-number pairs under the presence of process noise modeled as stochastic body forcing, in order to mitigate the system order expansion caused by state augmentation. The performance of reduced-order augmented estimators using reduced resolution sensing is compared to the benchmark performance full order estimators using full resolution sensing for a variety of wave-number pairs and disturbance scenarios.

GSC 2014 - The Annual Workshop of Graduate Students in Control

1. Student Name: Gilad Fursht
2. Student Affiliation & e-address: Faculty of Aerospace Engineering, Technion IIT, fugilad@tx.technion.ac.il.
3. Degree Studying Toward: M.Sc.
4. Thesis Supervisor: Prof. Moshe Idan.
5. Title of the Talk: Nonlinear Control Algorithms for Low-Cost Seeker Head.
6. Abstract:
Low-cost seeker head line-of-sight control design presents a great challenge due to system uncertainty and internal disturbances caused by the simple mechanical and electromechanical system components. Using conventional control, e.g. proportional-derivative or proportional-integral-derivative (PID) controllers cannot satisfactorily meet the performance characteristics in the whole seeker field-of-regard. Nonlinear control methods, especially robust methods, such Sliding-Mode-Control (SMC), may introduce enhanced capabilities to deal with system uncertainties and disturbances. In this talk, a comparison between the industrial commonly used PID controller and two Sliding-Mode Controllers – a conventional SMC and high order (2-SM) Super-Twisting SMC is described. The comparison is based on numerical simulation and laboratory tests carried out with a real low-cost seeker head. For controllers' performance comparison, two waveforms are injected to the control loop as inertial angular velocities commands: a) Step command, b) Sine wave command. Due to the structure of the given seeker head, a coupled two-inputs-two-outputs MIMO system, two main parameters of performance are compared: a) command following, b) coupling and disturbance rejection. The comparison clearly demonstrates the advantage of the robust nonlinear SMC methods in meeting system performance characteristics, given system uncertainty and disturbances.

Optimal Control of Bilateral Cooperative Teleoperation Systems with Delays

Liran Malachi[*] Advisor: Maxim Kristalny

Teleoperation systems are used to expand operator abilities to remote environments. In such systems, the operator uses an interface device, called a "master" in order to manipulate a robotic systems, referred to as a "slave". Bilateral teleoperation notion refers to the case in which haptic feedback is provided to operator contributing to a telepresence , i.e., to the operator's ability to feel the remote site.

In this talk, we concentrate on a control problem arising in cooperative bilateral teleoperation, i.e., in the case when multiple operators are manipulating a number of slave devices in a shared task environment. A situation like this may occur, for example, in a surgery with dual master consoles. One of the main challenges associated with such problems arises from communication delays, which in many practical cases may not be neglected, and render the associated control problem decentralized.

We show that by using Youla parameterization and introducing a special communication structure, the problem can be split into a three independent centralized optimizations with multiple delays. This, in turn, allows us to apply the recent loop shifting techniques for finding an efficient solution and revealing the optimal controller structure.

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Uncoded Transmission of Correlated Gaussian Sources over Broadcast Channels With Feedback

Yoni Murin, Ben-Gurion University, (supervisor Dr. Ron Dabora)

We study uncoded transmission of a pair of correlated Gaussian sources over a two-user Gaussian broadcast channel (GBC) with perfect feedback (PFB) links. Two linear coding schemes are considered: the Ozarow-Leung (OL) scheme and the coding scheme of Ardestanizadeh et al., which is based on linear quadratic Gaussian (LQG) optimal control theory. First, we derive an improved decoder for the LQG scheme which outperforms the original decoder in the finite horizon regime. Then, we show that in this regime, and in particular for independent channel noises, the OL scheme can outperform the LQG scheme with either of the decoders. This is in contrast to the infinite horizon regime in which the LQG scheme strictly outperforms the OL scheme. Furthermore, for the symmetric scenario with independent channel noises we provide an explicit characterization of the range of transmit powers for which the OL scheme outperforms the LQG scheme.

Title: On Boolean Control Networks with Maximal Topological Entropy

By: Dr. Dmitriy Laschov (I completed my PhD under the supervision of Prof. Michael Margaliot a short time ago).
School of Electrical Engineering-Systems, Tel Aviv University, Israel 69978
E-mail: dimal@eng.tau.ac.il

Abstract:

Boolean networks (BNs) are discrete-time dynamical systems with Boolean state-variables. BNs are recently attracting considerable interest as computational models for biological systems and, in particular, as models of gene regulating networks.

Boolean control networks (BCNs) are Boolean networks with Boolean inputs. The topological entropy of a BCN with m inputs is a nonnegative real number in the interval [0, mlog2]. Roughly speaking, larger topological entropy corresponds to a "more powerful" control, as it can steer the BCN to a larger set of possible states.

We derive a necessary and sufficient condition for a BCN to have the maximal possible topological entropy. Our condition is stated in the framework of Cheng's algebraic state-space representation (ASSR) of BCNs. This means that verifying this condition incurs an exponential time-complexity. We also show that the problem of determining whether a BCN has maximum topological entropy is NP-hard, suggesting that this problem cannot be solved in general using a polynomial-time algorithm.

Inertial Centering of High Speed Flexible Rotor Systems, Supported By AMBs

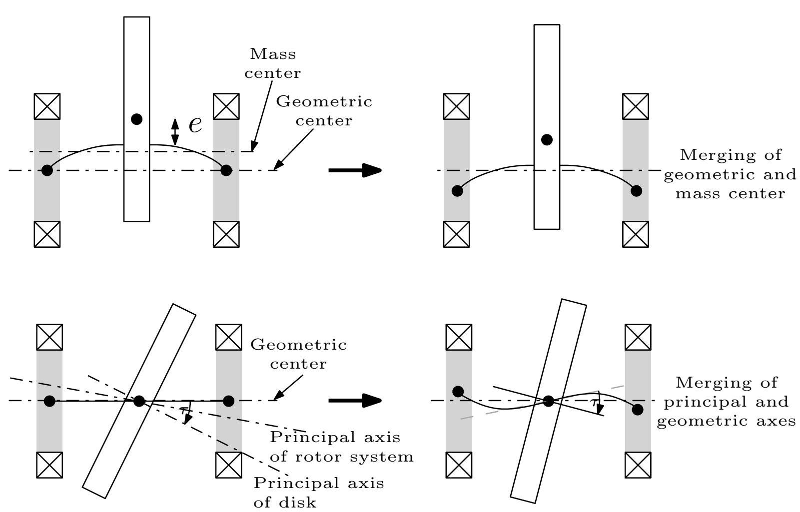
Student: Rami Levy, PhD candidate, email - levyram@post.bgu.ac.il

Affiliation: Department of Mechanical Engineering, Ben-Gurion University of the Negev

Supervisors: Dr. Shai Arogeti and Prof. Reuven Segev

Abstract

An inevitable physical phenomenon related to high speed rotating systems is undesired vibrations due to mechanical imbalance. In the absence of radial asymmetry, the steady state response of the rotor can be represented as a synchronous circular whirling motion. In this motion, the center of gravity of the shaft's cross section is moving in a circular orbit around the center of rotation, and the rotor's mass elements do not carry relative acceleration. Therefor, in these steady state conditions, the flexible rotor can be regarded as a rigid rotor. Motivated by this observation, a rigid body analysis is utilized in order to derive a set of constraint relations that are required for inertial centering, namely, for a rotation about the rotor's center of mass and its principal axis (as is illustrated below). The developed relations are based on a direct calculation of the shaft center of mass and on elimination of products of inertia from the shaft inertia tensor. In order to force the existence of the inertial centering constraints the shaft is supported by a set of active magnetic bearings (AMBs), and a suitable control system has been developed. The performances of the developed controller are demonstrated via numerical simulations.



Student Name: Adi Cohen

Student affiliations and e-address: Technion, adi745@gmail.com.

Degree Studying toward: M.Sc.

Thesis Supervisor: Asst. Prof. Yizhar Or

Title of Talk: "Dynamics and control of rehabilitative exoskeleton with robotic crutches":

The use of robots in daily life is growing rapidly every day, in various fields. One important robotic application is exoskeleton for walking rehabilitation used by paraplegics, which are required to operate crutches manually. In this study, we theoretically investigate the feasibility of exoskeleton walker with robotic crutches, which is supposed to be used by quadriplegics, who cannot operate crutches.

Our analysis focuses on the following:

1. Formulation of the dynamic equations of motion.
2. Computation of the control torques and contact forces required for maintaining no-slip contact.
3. Development of a simulation tool which will enable design of the robot's structure and actuation, planning of gait kinematics, and testing different feedback control strategies.

The research also focuses on the dynamic analysis of two main stages in the robot's movement cycle: a) Advancing the swing leg forward while maintaining no slip contact with the rest of the mechanism and b) Throwing the crutches forward in order to maintain another step in the walking cycle.

While in the first stage the number of degrees of freedom equals the number of actuators the second stage is under-actuated.

The last part of the research focuses on different techniques for achieving under-actuated motion along a desired trajectory.

Existing exoskeleton

Exoskeleton walker with robotic crutches

Analysis of the Ribosome Flow Model: A Linear-Algebraic Approach

Affiliations

- **Student**: Yoram Zarai, School of EE-Systems, Tel Aviv University, Tel Aviv, 69978, Israel, *yoramzar@mail.tau.ac.il* Studying toward Ph.D. degree.
- **Supervisor**: Prof. Michael Margaliot, School of EE-Systems and the Sagol School of Neuroscience, Tel Aviv University, Tel Aviv, 69978, Israel, michaelm@post.tau.ac.il

Abstract

Gene expression is the process by which information encoded in the genes is transformed into proteins. Protein synthesis begins with the *transcription* of the genetic information from DNA to mRNA and proceeds to *translation* of the mRNA to proteins. During translation, molecular machines called *ribosomes* move along the mRNA chain, decoding triplets of mRNA nucleotides (called codons) into a chain of amino acids that is then folded into a protein. The translation process occurs in all organisms, in almost all cells and in almost all conditions. Thus, understanding translation has important implications in many scientific disciplines, including medicine, biotechnology, and evolutionary biology.

The *ribosome flow model* (RFM) is a deterministic mathematical model for the movement of ribosomes along the mRNA chain. It consists of n first-order, nonlinear ordinary differential equations and $n+1$ parameters: the initiation rate λ_0 and elongation rates λ_i, $i = 1, 2, \dots, n$, between the consecutive sites.

Let R denote the steady-state translation rate in the RFM. In this talk, we show that $R^{-1/2}$ is the Perron root of a symmetric, non-negative tridiagonal matrix whose entries depend on the RFM parameters. We describe several implications of this result in the context of the biological process of translation.

Flight Control Law Clearance using Optimal Control Theory

Avriel Herrmann MSc Candidate

Supervisor: Joseph Ben-Asher

Flight control law clearance is the practice of ensuring the safety of an aircraft for all admissible pilot inputs under all possible conditions. To date, the method used in industry is to divide the parameter space into a grid and test the flight control law for a finite number of manoeuvres. An alternative approach is optimization; instead of showing that a flight control law is valid under all possible conditions, the worst aircraft behaviour is sought, and if it can be demonstrated that the behaviour is within acceptable limits, then the flight control law is valid.

The purpose of this work is to determine whether optimal control techniques can be applied to flight control law clearance, in order to solve the problem in a format that is familiar to control engineers. The focus is on Angle-of-Attack (AoA) limit exceedance. Using optimal control theory and General Pseudospectral Optimal Control Software (GPOPS), it is shown that the unbounded system achieves a maximum AoA with a 'bang-bang' pilot input, while the system with bounds on the elevator has a 'bang-singular' worst case pilot input. Applying test inputs to a more complex model, shows that overall the 'bang-singular' input produces the worst aircraft behaviour.

Student Name: Ari Berger
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Degree Studying toward: M.Sc
Thesis Supervisor: Prof. Per-Olof Gutman

Title of Talk: "A new view of anti-windup design for uncertain linear systems in the frequency domain"

Abstract:

Actuator limitations are a well-known practical problem. A saturated actuator can cause the system to become unstable or exhibit limit cycles. A well-known case for instability is integral windup which was first noticed in PID controllers. Windup is then interpreted as an inconsistency between the controller output and the states of the controller. The problem of stabilization becomes even harder when uncertainty is present in the plant.

This talk presents a somewhat new perspective on the stability problem for uncertain LTI feedback systems with actuator input amplitude saturation. The solution is obtained using the QFT theory and a 3 Dof non-interfering control structure. Describing function analysis is used as a criterion for closed stability and limit cycle avoidance, but the Circle or Popov criteria could also be employed. The novelty is the parameterization of the three degrees of freedom. Two examples are given. The first is a benchmark problem and a comparison is made with other proposed solutions. The second is an example which was implemented and tested on an X-Y linear stage used for nano-positioning applications. Design and implementation considerations are given.

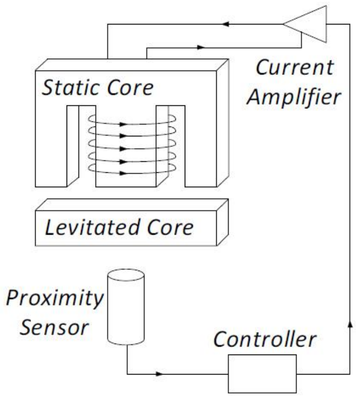
Iterative Output Control of an Active Magnetic Bearing based Suspension System

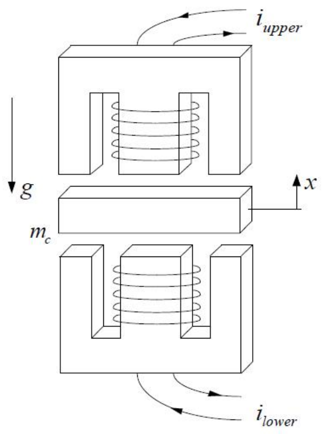
Student: Sergei Basovich, PhD candidate, basovich@post.bgu.ac.il
Affiliation: Department of Mechanical Engineering, Ben-Gurion University of the Negev
Thesis Supervisor: Shai Arogeti

Abstract

Active Magnetic Bearing (AMB) technology based actuators are highly relevant for practical purposes. However, in many applications, the payload of the actuator is frequently replaced and its value is poorly estimated or unknown. In addition, although the electromagnetic coefficient can be estimated by some finite element analysis, the evaluation of its real value for a particular plant is still not an easy engineering task. The listed above difficulties, in couple with the nonlinearity of the actuator-force and the fact that the prevalent configuration of an AMB system doesn't include velocity sensors, rise the need to use appropriate control techniques in order to ensure adequate operation of AMB based systems.

This presentation is about synthesis, analysis and implementation of an iterative output-feedback control scheme for a single degree of freedom active magnetic bearing based suspension system. The presented control law is based on the feedback linearization method, where the payload and the electromagnetic coefficient are assumed unknown. The adaptation module of the controller is based on the contraction mapping theorem. The presented controller was verified experimentally.





Coordinated Path following of Autonomous Vehicles

Student: Itai Arad, studying toward M.Sc. degree, itaiara@post.bgu.ac.il
Affiliation: Department of Mechanical Engineering, Ben-Gurion University of the Negev
Thesis Supervisor: Shai Arogeti

Abstract

A new control algorithm is presented for the coordinated path following problem of a group of autonomous vehicles. This controller is based on a simplified vehicle model where the vehicle wheels sideslip angles are not ignored. A nonlinear path following controller was designed and its stability is shown by the Lyapunov approach. Two observers are introduced in order to allow the necessary online estimation of the vehicle sideslip angels and its wheels cornering stiffness coefficients. The developed controller is demonstrated for a group of vehicles in scenarios which includes path following, speed control and collision avoidance.

The main contribution of this work stems from the inclusion of the extended bicycle kinematical model in the development (which is preferred for high speed maneuvers), and the extension of the null-space-behavior (NSB) algorithm (which was originally developed for unicycle mobile robots) to the car-like vehicle. The stability of the coordinated path following controller was proven and its effectiveness was demonstrated using numerical simulations and the Carsim© software package.

Trajectory Planning for Engine-Shutdown Emergency in General Aviation Aircraft

Yuri Osokin, Technion

Supervisors: Prof. Nahum Shimkin & Aharon Bar-Gil

We develop a real-time numeric algorithm for global planning of an energy-efficient trajectory for a General Aviation (GA) aircraft in case of an engine shutdown emergency. Planning and following an efficient trajectory towards a landing site may be a challenging task for the pilot in such a stressful situation, and the automatically planned trajectory is intended as an on-line assistant for this situation.

We formulate the problem as an optimal control problem with the goal of minimizing the energy loss along the trajectory, under the constraints of flight dynamics and in the presence of topological and man-made obstacles. We use a six-dimensional dynamic aircraft model, that fits a wide range of GA aircraft and provides a reliable estimate of the energy loss. We coarsely discretize the solution domain with a regular grid, consistent with the model dynamics, and construct optimal trajectories between coarse grid points using optimized Motion Flight Primitives. A modified Dijkstra algorithm for optimal graph search connects theseMotion Flight Primitivesfrom the current aircraft state to the landing site.

Performance of the suggested algorithm is demonstrated using a Cessna 172 aircraft model parameters.