Program

תכנית

08:15–09:00	Registration
09:00–09:10	Opening
09:10–09:45	*Sliding-Mode Based Differentiation in Missile Guidance Application* Joseph Z. Ben-Asher (Technion)
09:45–10:20	*Midcourse Guidance Using Neural Networks* Natan Grinfeld, Itzhak Yaesh (Elbit) and Joseph Z. Ben-Asher (Technion)
10:20–10:55	*Linear Quadratic Minimum Effort, Specify Performance Approach to Missile Guidance* Martin Weiss and Tal Shima (Technion)
10:55–11:25	Coffee / tea break
11:25–12:00	*Simple All-Aspect Guidance Law* Erez Sigal and Haim Weiss (RAFAEL)
12:00–12:35	*Adaptive Proportional Navigation Guidance* Haim Weiss, Ilan Rusnak and György Hexner (RAFAEL)
12:35–13:45	Lunch
13:45–14:20	*Loop-Shaping Approach to Mitigate Radome Effects in Homing Missiles* Itzik Klein (U Haifa) and Ilan Rusnak (RAFAEL)
14:20–14:55	*LQ / H_∞ (soft) vs. Unit Vector (stiff) Guidance* Shaul Gutman (Technion)
145:55–15:30	*Near-Optimal Evasion from Pursuers Employing Modern Linear Guidance Laws* Vitaly Shaferman (Technion)
15:30–15:50	Coffee / tea break
15:50–16:25	*Optimal guidance laws with prescribed degree of stability* Ilan Rusnak, Haim Weiss and György Hexner (RAFAEL)
16:25–17:00	*Minimum-Effort Impact-Time Control Guidance Using Quadratic Kinematics Approximation* Gleb Merkulov, Martin Weiss, and Tal Shima (Technion)
17:00	Closing

speaker names are underlined

שמות המרצים מודגשים בקו

איב"א
איגוד ישראלי לבקרה אוטומטית

ארגון לאומי חבר ב-IFAC ו-IAIN

תקצירי הרצאות יום העיון של איב"א בנושא

הנחיית טילים

מלון דניאל, הרצליה

י"ב בחשון, תשפ"ב (18 באוקטובר 2021)

מארגן: **חיים וייס** (רפאל)

תודתנו נתונה לארגונים להלן, אשר תמיכתם מאפשרת לקיים ימי עיון מעין זה

– אלביט מערכות בע"מ –
– אפלייד מטיריאלס ישראל בע"מ –
– הקריה למחקר גרעיני – נגב ע"ש שמעון פרס –
– סיאלו פתרונות אינרציאליים בע"מ –
– רפאל – מערכות לחימה מתקדמות בע"מ –

09:10–09:45

Sliding-Mode Based Differentiation in Missile Guidance Application

Joseph Z. Ben-Asher (Technion)

Abstract:

Sliding Mode Based Differentiation is employed in missile guidance application to obtain line-of-sight rates from noisy measurements. Under proportional navigation guidance, the resulting miss-distances are comparable with Kalman Filter's results and outperform simple linear filters. Sliding-mode based target maneuvering estimation is shown to be a promising approach for augmented proportional navigation, with a very low time delay and sufficient accuracy. Sliding Mode Based Differentiation with filtering is important when the noise level is high, and can be further optimized to improve the performance.

09:45–10:20

Midcourse Guidance Using Neural Networks

Natan Grinfeld, Itzhak Yaesh (Elbit) and Joseph Z. Ben-Asher (Technion)

Abstract:

Midcourse guidance in missiles may be performed in several methods, ranging from ad-hoc maneuvers for optimal glide/ascent/descent/turn, predictor-corrector type guidance using a prediction of zero effort miss to calculate the required maneuver, and methods of following a trajectory which is aimed at minimization of a cost function weighing of all design objectives while satisfying hard constraints. Following such pre-designed trajectory allows exploiting the missile's operational capabilities to the maximum. It suffers, however, from flaws, such as requiring a large amount of offline computations to achieve pre-designed trajectories for the entire operational envelope, as well as needing fast real-time trajectory data retrieval from a mass storage device. Furthermore, it is optimal only for the designed trajectory conditions and the underlying missile model parameters. As the missile deviates from those conditions in real-time, it loses optimality as it maneuvers in order to follow the original trajectory which is not relevant anymore. A possible remedy to the latter robustness problem is provided by the method of Neighboring Extremals (NE), where the pre-designed trajectory is perturbed by generation of corrective state feedback-type maneuvers which transfer the missile to a near optimal trajectory, when the above deviations are small enough. Besides the fact that NE implementation is a heavy computational task (e.g. solving a TPBVP in real time), it cannot deal with large deviations. One would prefer an efficient calculation, in real-time, of either the required trajectory or acceleration commands, based on the current state, so as to obtain a trajectory which is near optimal in the presence of a prescribed ball of parameter and state vector deviations, which are not necessarily small. The latter objective, served as the motivation for the present research.

In this research, a neural network was trained based on optimal trajectories produced using GPOPS implementation of a point mass model of the missile. Selected parameters of the missile's state, along with target location and requirements, were given as an input to the network at each point along a calculated optimal trajectory. The required maneuver (implemented as angle of attack) for this current state was set as the desired output for the network training. The neural network was trained using this method around a reference trajectory, where each point of this reference trajectory served as a starting point for a new trajectory to the same original target. Furthermore, each original point in the trajectory was perturbed in some of the initial conditions (Mach number, altitude and path angle) to create multiple cases of training data that cover a region around the original reference trajectory. After training the neural network to a satisfactory level of accuracy, it was implemented in a 3DOF simulation and was used to provide a required control (AOA) based on current missile state and target data. The network seems to virtually replicate the original reference trajectory, also providing generalization capabilities, as trajectories of varying range, azimuth, and launch altitude, launch angle were also executed successfully, thus proving the concept of using a neural network to provide guidance commands in midcourse guidance. The issues to be examined in further research of this subject include: test of the robustness of this network to changes in aerodynamic model or the effect of wind, the effect of noise on the network inputs on its performance, stability analysis of such network within a full control scheme, the use of more than one reference trajectory and the minimal required number of such trajectories to fully cover the operational envelope, and finally the implementation of the network in full 6DOF simulation.

10:20–10:55

Linear Quadratic Minimum Effort, Specify Performance Approach to Missile Guidance

Martin Weiss and Tal Shima (Technion)

Abstract:

A generic guidance design framework is proposed that is based on the idea of minimizing the guidance effort expressed as the quadratic integral of the guidance command and imposing performance constraints on various trajectory parameters at arbitrary points in time during the flight. This framework extends previous work on guidance algorithms for active aerial defense and for obstacle avoidance. Using some concrete examples it is shown that the proposed framework is flexible enough to tackle interesting guidance problems related to multiple targets scenarios. It is also shown that the same framework offers a practical solution for the optimal intercept guidance problem with constraints on the lateral missile acceleration.

11:25–12:00

Simple All-Aspect Guidance Law

Erez Sigal and Haim Weiss (RAFAEL)

Abstract:

The work presents simple 3D all-aspect guidance law in which the acceleration command is proportional to the relative heading error. The proposed law enables the missile to intercept a maneuvering target under any initial heading conditions. The new guidance law takes care of

time-varying velocities and guarantees fast convergence to a collision course. The performance of the new law is demonstrated via simulation.

12:00–12:35

Adaptive Proportional Navigation Guidance

Haim Weiss, Ilan Rusnak and György Hexner (RAFAEL)

Abstract:

The paper presents the Proportional Navigation (PN) guidance loop as a tracking loop with the line-of-sight rate as the tracking error. This presentation enables the derivation of a new guidance law via direct implementation of the Simple Adaptive Control (SAC) algorithm. There are two main innovations in the proposed guidance law: (1) the presence of the parallel feed-forward controller (PFC), which is equivalent to adding a derivative of $\dot{\lambda}$ to the control signal, and (2) the adaptive form of the navigation gain. In the present work the structure of the PFC is obtained via an optimization procedure. The stability of the adaptive guidance system with the selected PFC is validated via simulation. The simulation of the zero dynamics assures that the linear time varying controlled plant is Almost Strictly Passive (ASP) and, as a result, guarantees the stability of the adaptive guidance. The paper demonstrates the performance of the Adaptive Proportional Navigation (ADPN) and shows a significant improvement in performance comparing to PN.

13:45–14:20

Loop-Shaping Approach to Mitigate Radome Effects in Homing Missiles

Itzik Klein (U Haifa) and Ilan Rusnak (RAFAEL)

Abstract:

The work presents the derivation of the newly proposed loop-shaping approach and demonstrates the reduction of the radome parasitic loop effects. The constant radome case is dealt with to demonstrate and analyze the effect of the compensation network approach on stability and miss distance performance via loop shaping. This is done in the frequency domain by Nichols charts. It is shown that appropriate loop shaping prevents instability in the guidance loop.

14:20–14:55

LQ / H_∞ (soft) vs. Unit Vector (stiff) Guidance

Shaul Gutman (Technion)

Abstract:

The class of Linear Guidance laws, such as LQ / H_∞, are soft in nature. They are based on a cost function formed of a terminal part (miss-distance) and a control effort part. Thus, if initially, two players lie on a collision course; that is, the ZEM (zero-effort-miss) vector vanishes, they will continue doing so, until collision. However, the evader will never agree to collaborate with such a game rule. Instead, he will use all his capability to increase the miss-distance. Yet, this class of guidance strategies is simple to generate to a wide range of systems. On the other hand, a Unit Vector Guidance applies all its acceleration in the direction of the ZEM vector. In this case, the ZEM vector never vanishes, or chatters. However, this approach is limited to a certain class of systems. In this presentation we bridge the gap between the Unit Vector Guidance law, which is stiff in nature, and the LQ soft approach. This is done by investigating time-to-go. As a result, we declare a new class of guidance laws, easy to generate, and stiff in nature.

145:55–15:30

Near-Optimal Evasion from Pursuers Employing Modern Linear Guidance Laws

Vitaly Shaferman (Technion)

Abstract:

Near-optimal evasion strategies, from pursuers that employ modern linear guidance laws, are proposed. Most modern guidance laws rely on the evader's acceleration to minimize miss distance. However, the evader's acceleration cannot be directly measured and needs to be estimated. The key idea underlying the proposed approach is to exploit the inherent time delay associated with the pursuer's estimate of the evader's acceleration to maximize the miss distance. This problem is posed in a bounded target acceleration optimal-control framework with linear pursuer and evader dynamics of arbitrary order. The evader is assumed to have perfect information on the pursuer's states, parameters, and guidance law. The pursuer is assumed to have perfect information on the evader's parameters and states; however, the pursuer's estimate of the evader's acceleration is assumed to have a pure delay. The optimal evasion strategies are derived, analytically studied, and extensively evaluated in linear, deterministic and nonlinear, stochastic Monte Carlo simulations. The proposed evasion strategies against this class of pursuers substantially increase the miss distance when compared with strategies that do not exploit estimation delay.

15:50–16:25

Optimal guidance laws with prescribed degree of stability

Ilan Rusnak, Haim Weiss and György Hexner (RAFAEL)

Abstract:

The prescribed degree of stability criterion is used. This quadratic criterion involves an increasing exponential time dependent term in the integral part of the criterion. This criterion is used for derivation of guidance laws. The derived guidance law has the classical structure of guidance gain times the zero-effort miss. The important issue is the fact that initially the guidance gain and thus the commanded acceleration are larger than in the conventional Proportional Navigation guidance law, but near the end, the commanded acceleration is smaller. The new guidance law attempts to close the zero effort miss earlier in the scenario than the conventional guidance law.

16:25–17:00

Minimum-Effort Impact-Time Control Guidance Using Quadratic Kinematics Approximation

Gleb Merkulov, Martin Weiss, and Tal Shima (Technion)

Abstract:

Impact-time control guidance is a framework to coordinate the missile arrival in salvo-attacks to overwhelm the target and ensure the defense penetration. In this talk, we propose an effort-optimal solution for such a problem relying on the quadratic approximation of the missile-target kinematics. It is shown, that the optimal control problem has, in general, a unique solution. Based on this solution, a guidance law is proposed that is shown to be implementable based on typically available sensor data, using a semi-analytic procedure. Numerical simulations show that the solution based on the second-order approximate kinematics matches closely the solution based on the original nonlinear kinematics that can only be obtained by numerical optimization.