The **French-German Research Institute of Saint-Louis (ISL)** situated in the border triangle of Germany, France and Switzerland is an internationally renowned research institute belonging to a global industrial and economic network.
The spectrum of our core activities comprises a variety of topics: aerodynamics, energetic and advanced materials, lasers and electromagnetic technologies, protection, security and situational awareness. Our activities are related to both basic and applied research.

ISL is offering a **PhD Position**

Research field: Flight techniques for projectiles

Flight dynamics of an improved spin-stabilized canard-guided projectile

Motivation

Standard ballistic artillery ammunition used in current theaters of operation suffers from a relatively large on-target dispersion due to various factors such as wind shears, uncertain launch conditions, etc. A solution to this problem is to retrofit these projectiles with a nose-mounted guidance module which is decoupled from the body through a co-axial motor or aerodynamic canard action. The guidance module should contain all necessary hardware (actuators, sensors, computing devices) and software (autopilot, guidance laws, flight sequencer, navigation algorithms etc.) needed in order to achieve a smooth and controlled flight to the target. The autopilot is especially important for any guided vehicle since its robustness and performance dictates the limit of the weapon precision. The design of the autopilot needs to be perfectly mastered across the whole flight envelope and in the presence of various hardware limitations and aerodynamic uncertainties.

State of the art

ISL has an established know-how in the design of simulation tools for spin-stabilized canard-controlled projectiles. The proposed work will be the continuation of internally funded background work and also of a PhD project which met with great success in 2016 and was co-funded by DGA and ISL. In total, four high impact-factor journals were produced as well as several internal and external communications. Most importantly, realistic virtual reality nonlinear simulators of the system have been obtained which illustrate that guidance and control of such a weapon is feasible to within a few meters of the target in ballistic range. Even though significant work was performed on the subject, there remain open issues to study, as pointed out below.

Research proposal

The future axes of research that are proposed for the next generation course-correction guided projectiles are detailed below:

Linear and Nonlinear Modeling:

1. More realistic projectile nonlinear models (aerodynamics obtained from CFD, high alpha models, non-symmetric fuse) which take into account the environment (winds, turbulence, gravity) as well as more potential sources of uncertainty.
2. Guidance fuse angular position control using aerodynamic and non-mechanical control as well as investigation of reduced control authority schemes such as Bank-To-Turn (BTT) or Bank-While-Turn (BWT).
3. Equilibrium point computation using the accelerations instead of angles of attack in order to reduce trim point uncertainty and improve gain-scheduling. Design of flight envelope protection schemes to maximize weapon maneuverability.
4. More efficient LPV/LFR model computations using latest open-source software tools.

Flight control

1. Comparison of various LTI autopilot design tools and schemes such as multi-objective (mixed H2/Hinf, robust feedforward) and multi-model to better cope with operating point fluctuation. Comparison of fixed-order and full-order controller designs.
2. Investigating gain-scheduling schemes which make it possible to directly design autopilot gain surfaces to accelerate development.
3. Including robust performance requirements against system uncertainties and use of latest mu-analysis tools.
4. Taking into account discrete time implementation and computational delays directly from the design phase.
5. Comparison with nonlinear and rapid prototyping control schemes such as dynamic inversion.

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