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Flight control for air-breathing hypersonic vehicles using linear quadratic regulator design based on stochastic robustness analysis

Key words: Air-breathing hypersonic vehicles; Stochastic robustness analysis; Linear-Quadratic regulator; Particle swarm optimization; Improved hybrid PSO algorithm

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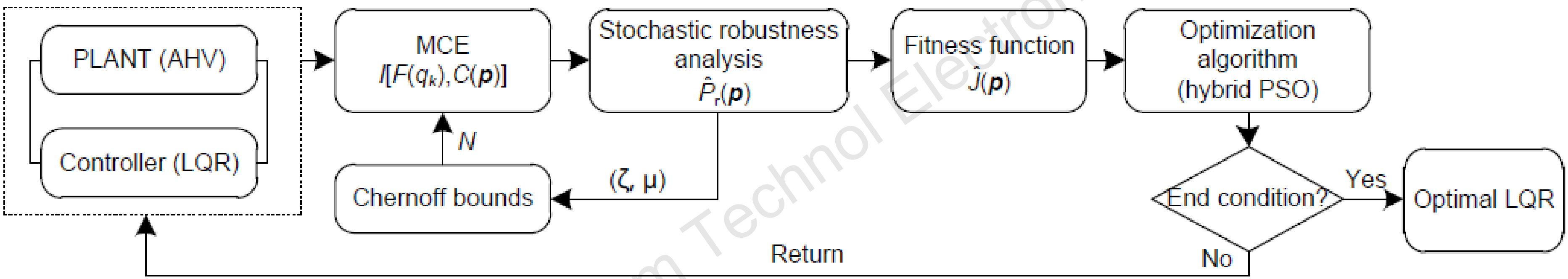
Introduction

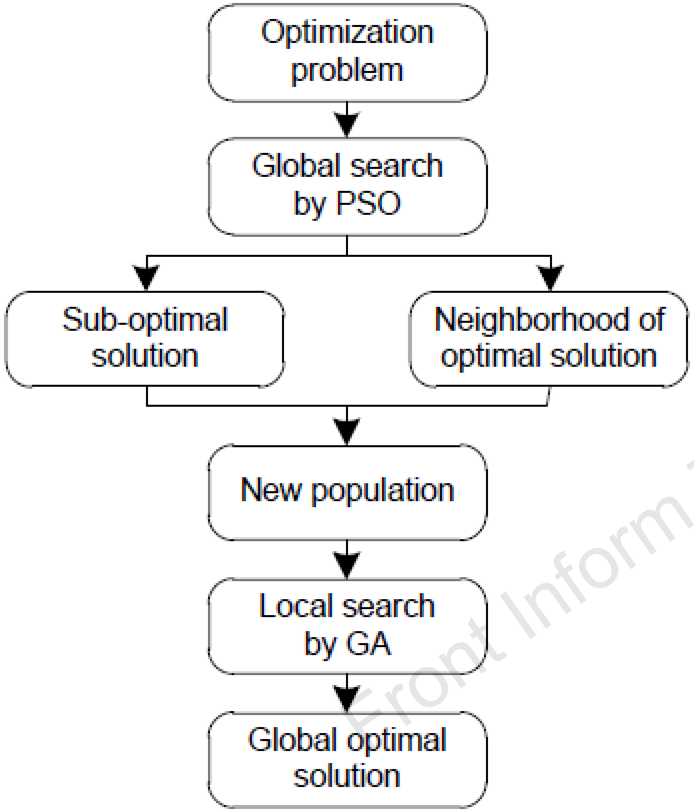
- The fomer investigaition on SRA focused mainly on robustness measurement and analysis, and gave little attention to stochastic evaluation and optimization algorithms .
- A novel improved hybrid PSO algorithm is proposed to search for the optimal LQR parameters.
- Chernoff bounds is applied to determine the finite sample size of Monte Carlo evaluation with given probability levels.

Flow diagram of LQR design based on SRA

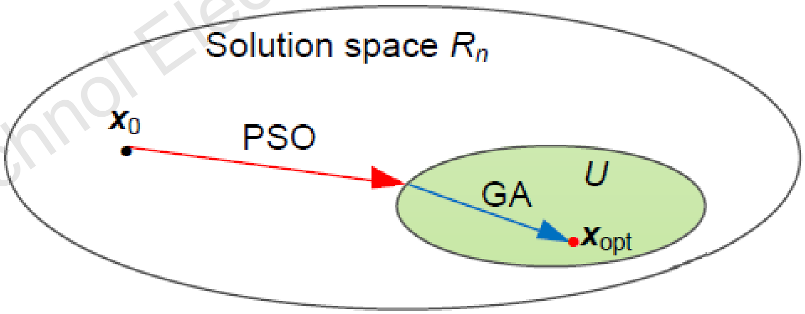


LQR-SRA control strategy.

Hybrid PSO algorithm

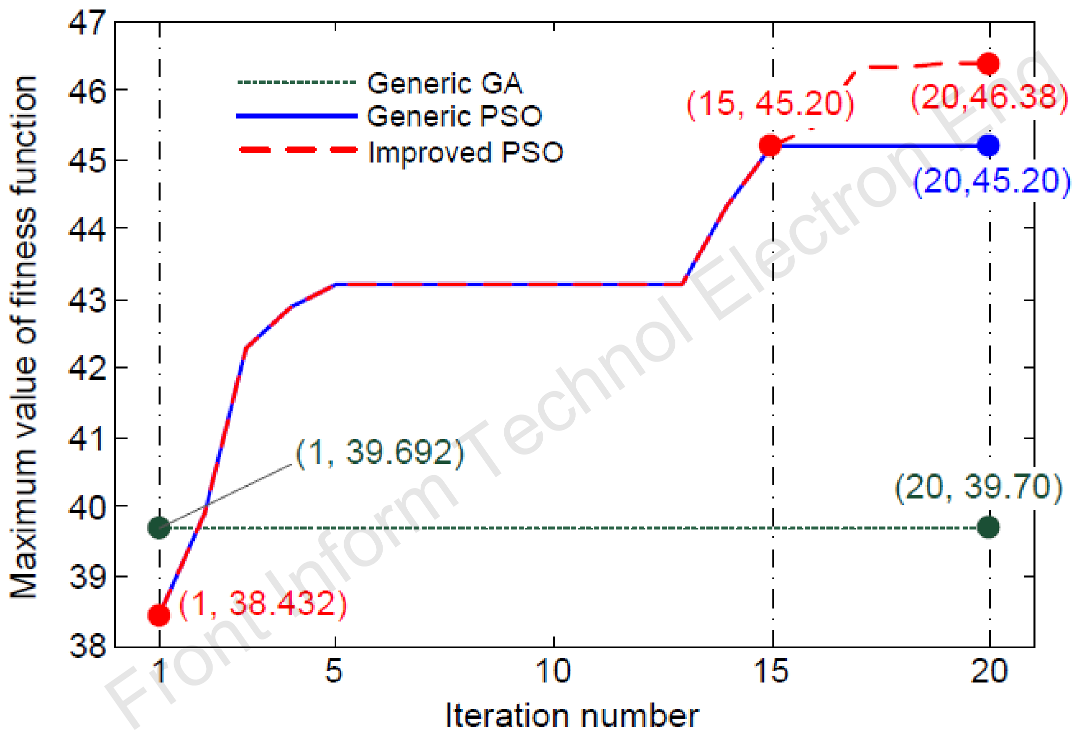


Algorithm procedure.



Algorithm sketch map.

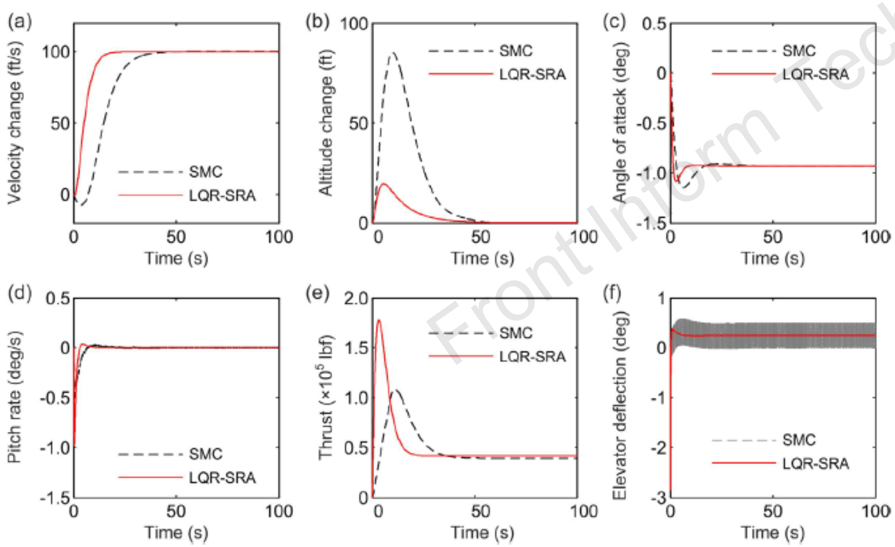
Simulation results (1): optimal algorithm analysis



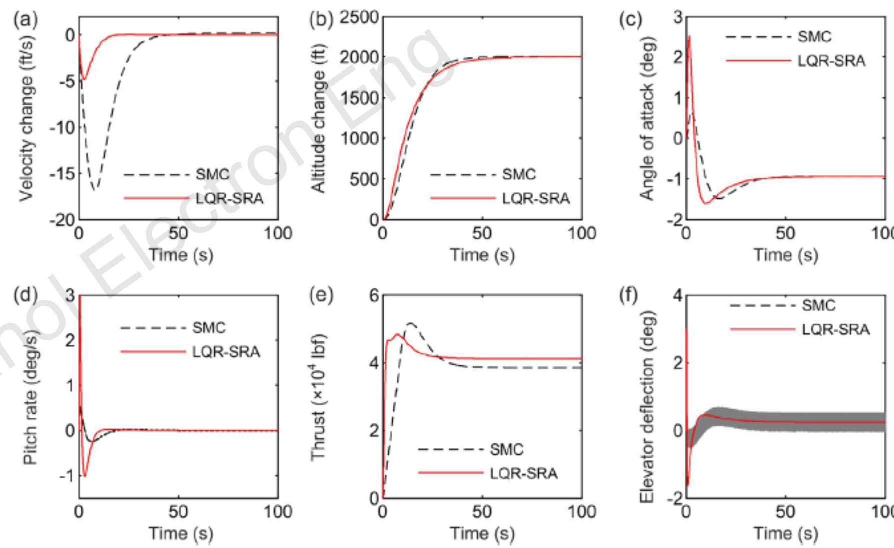
Optimal algorithm comparison.

Simulation results (2): closed-loop system response

As shown in both figures, compared to SMC, LQR-SRA shows faster convergence velocities and more steady tracking trajectories in both velocity and altitude channels, and offers more steady elevator deflection.



Response to a step-velocity command.



Response to a step-altitude command.

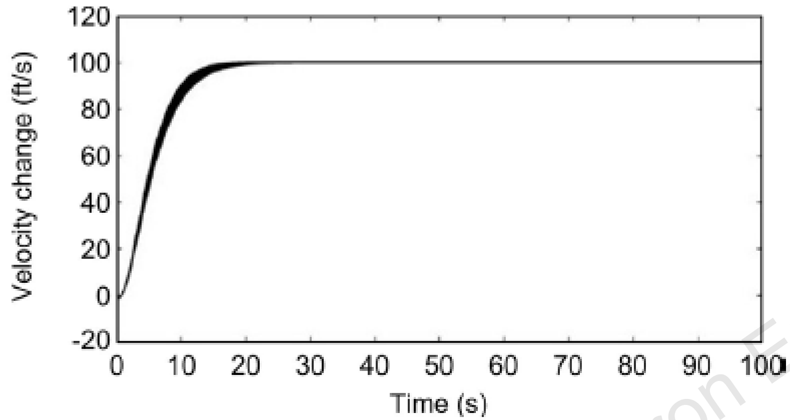


Fig. 8 Stochastic response with LQR-SRA to a 100-ft/s step-velocity command

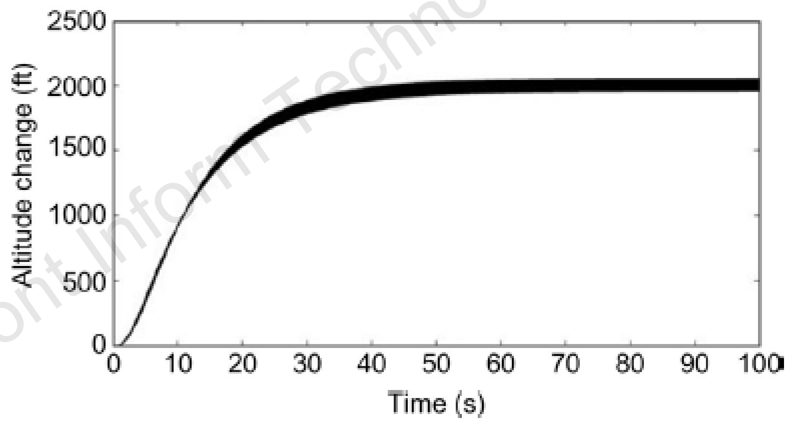


Fig. 9 Stochastic response with LQR-SRA to a 2000-ft step-altitude command

Stochastic responses.

Conclusions

- The improved hybrid multi-objective PSO algorithm can effectively find out the best solution to LQR parameters in a large span of design parameter space.
- According to response to a 100 ft/s step-velocity command and a 2000 ft step-altitude command results, the optimal LQRs have good performance and robustness in the presence of parametric uncertainties.