TEXAS A&M ENGINEERING EXPERIMENT STATION

Projection-Based Inter-Agent Collision Avoidance in Dual Agent Systems*

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Introduction: Transient Stability in Leader Follower Systems

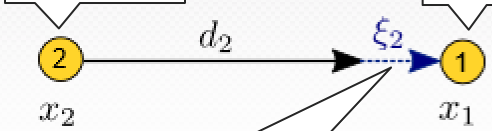
- *Relative error feedback* is a common approach in designing autonomous leader-follower systems that maintain some fixed separation vector.

Follower

Leader

The follower applies the control:

$$u_2 = GC\xi_2$$



Relative Error Vector

The leader and follower are identical LTI systems.

Relative error dynamics

$$\dot{\xi}_2 = (A - BGC)\xi_2 + Bu_1$$

- If the closed-loop matrix (A-BGC), of the relative dynamics, is Hurwitz, then the relative error vector is exponentially stable.

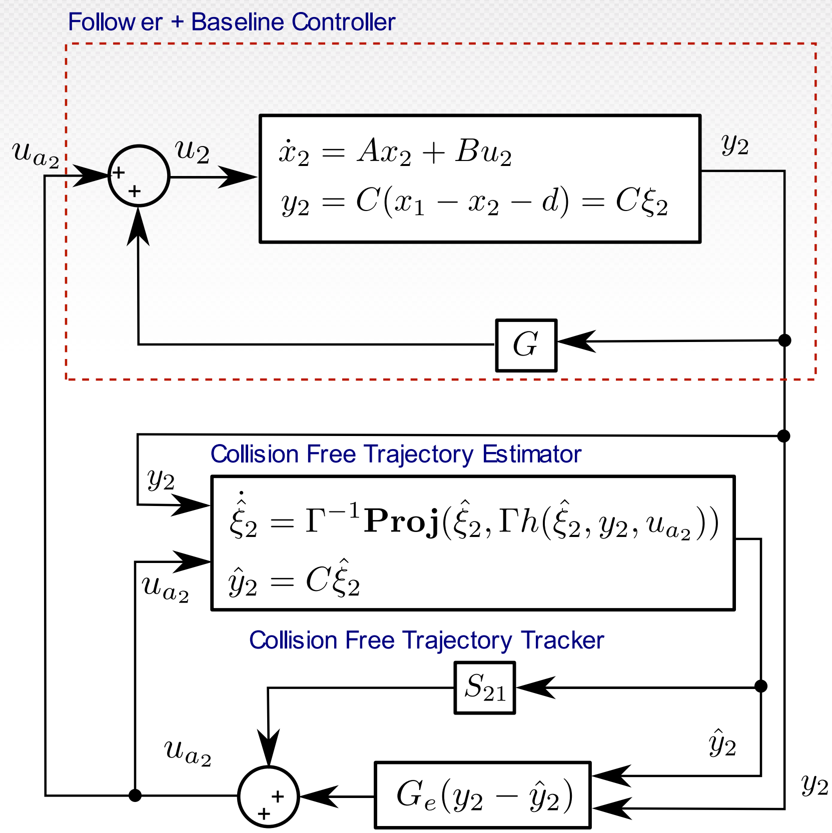
- Unfortunately, *even though the relative error dynamics are exponentially stable*, *collisions* between the leader and follower *can still occur due to transient dynamics* resulting from off-nominal initial conditions and external disturbances.

TRANSIENT STABILITY	• *A leader follower is transient stable* if the closed loop matrix of the relative error vector, *(A-BGC), is Hurwitz*, and the relative error vector evolves so that the *follower's trajectory ($x_2(t)$) evolves collision free*.

Projection Based Approach to Transient Stability in Leader-Follower Systems

- Projection operator based approach to transient stability consists of *three components*:
  - *Baseline controller*: relative error feedback for formation maintenance.
  - *Projection based estimator*: generates collision free estimator trajectory by estimating the relative error vector.
  - *Estimator tracking controller*: a servomechanism for the relative error vector to track the collision free relative error trajectory generated by the projection based estimator.
- Together, the three controller components provide transient stability, satisfying the relative error constraint

$$\| \xi_2(t) \| \le (1-\alpha) \| d_2 \| .$$



Main Results: Collision free Estimator and Tracking controller Stability.

- **Theorem** (Collision Free Estimator Stability): The error trajectory

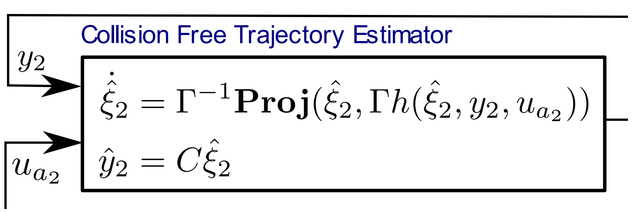
$$e(t) \equiv \hat{\xi}_2 - \xi_2,$$

of the estimator dynamics

$$\dot{\hat{\xi}}_2 = \Gamma^{-1}\mathbf{Proj}(\hat{\xi}_2, \Gamma h(\hat{\xi}_2, y_2, u_{a2}))$$

$$\hat{y}_2 = C\hat{\xi}_2,$$

is exponentially stable.



- **Theorem** (Reference Model Tracking): The follower LTI system

$$\dot{x}_2 = Ax_2 + Bu_2$$

$$y_2 = C(x_1 - x_2 - d_2) = C\xi_2$$

with the tracking control law

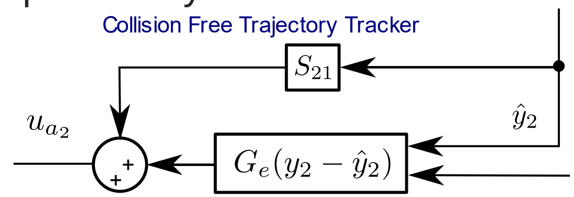
$$u_{a_2} = G_e(y_2 - \hat{y}_2) + S_2\hat{y}_2,$$

will track the estimated trajectory system

$$\hat{\xi}_2(t) = L\phi(t)$$

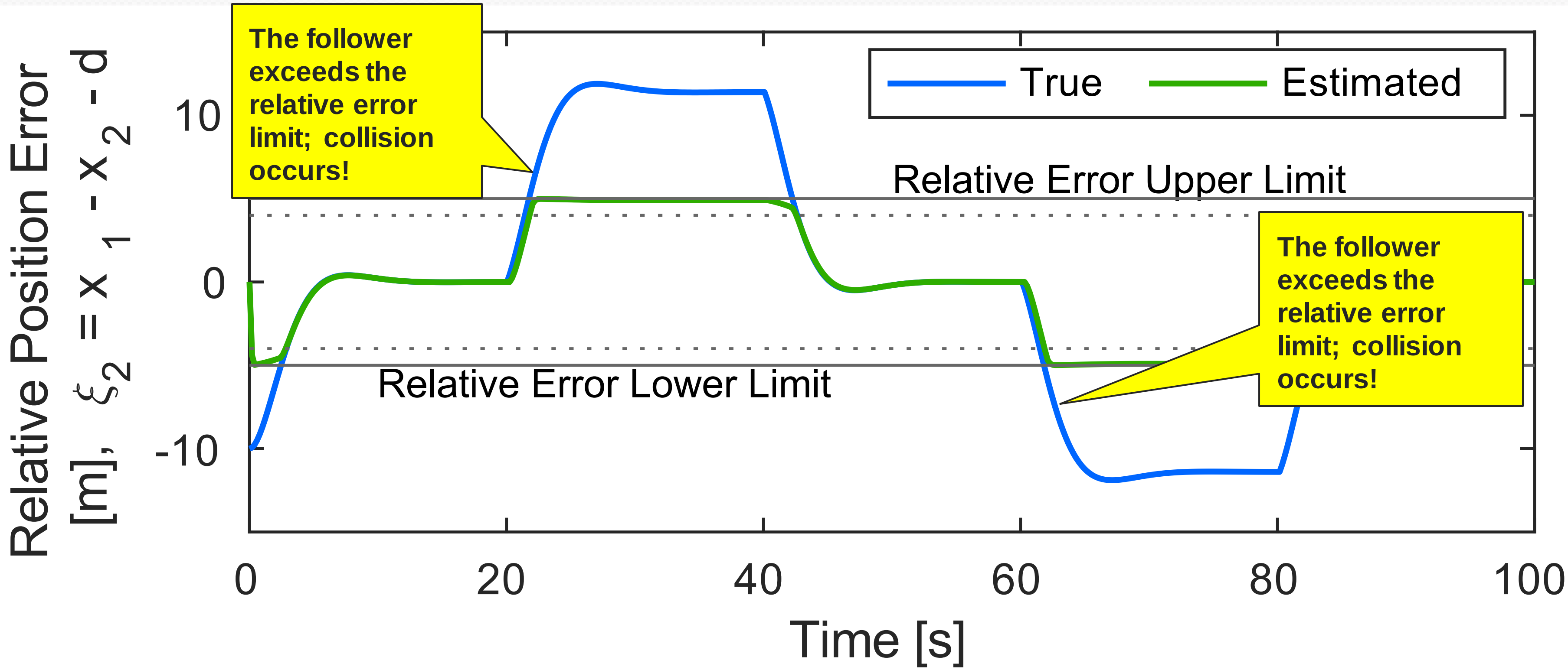
$$\hat{y}_2 = C\hat{\xi}_2(t),$$

such that, the tracking error trajectory is exponentially stable.



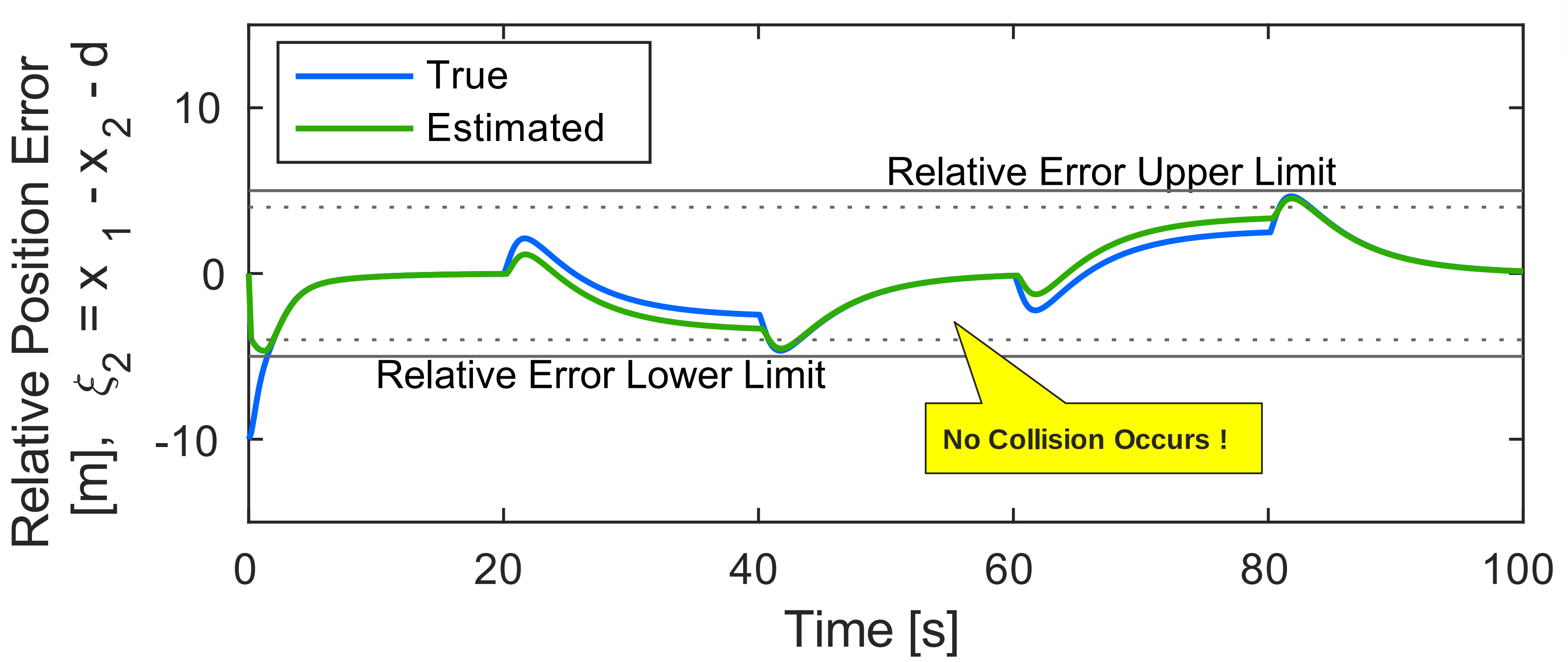
Simulation Result: Baseline Controller with Projection Based Tracking Disabled

- In this simulation, the *leader and the follower are double integrator systems*, and the follower maintains a distance of 10 meters with respect to the leader. Here, *both the baseline controller and the projection based estimator are enabled, but the tracking controller is disabled*.



Simulation Result: Baseline Controller with Projection Based Tracking Enabled

- In this simulation, the *leader and the follower are double integrator systems*, and the follower maintains a distance of 10 meters with respect to the leader. Here, the follower is equipped with the *baseline controller, the projection based estimator, and the tracking controller*.



Conclusion:

- The novel control architecture addresses the issue of transient stability in leader-follower dual agent systems, and the results presented are preliminary.
- The following technical challenges, relating to transient stability, will be addressed in the sequel to this work:
  - The combined stability of the projection estimator and the tracking controller error vector,
  - Generalize the control architecture to general N-dimensional multi-agent systems,
  - Control and stability results in the presence of external disturbance and noise.

Thank you!

Paper Title : “Projection-Based Inter-Agent Collision Avoidance in Dual Agent Systems.”

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