Generation of Dynamically Feasible and Collision Free Trajectory by Applying Six-order Bezier Curve and Local Optimal Reshaping

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IROS 2015

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CS686

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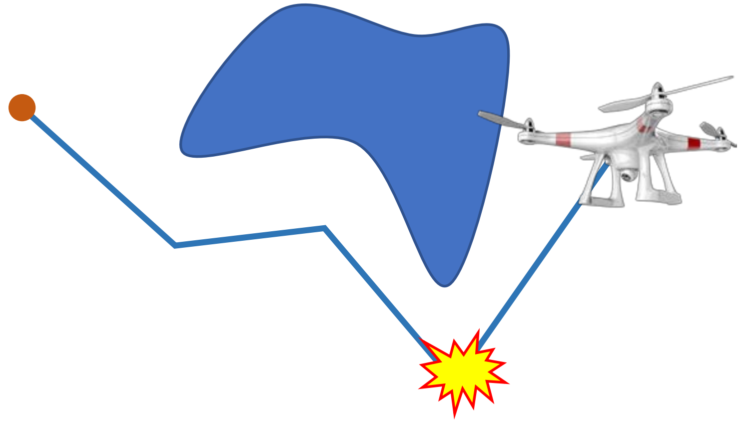
◆ Problems of the paper

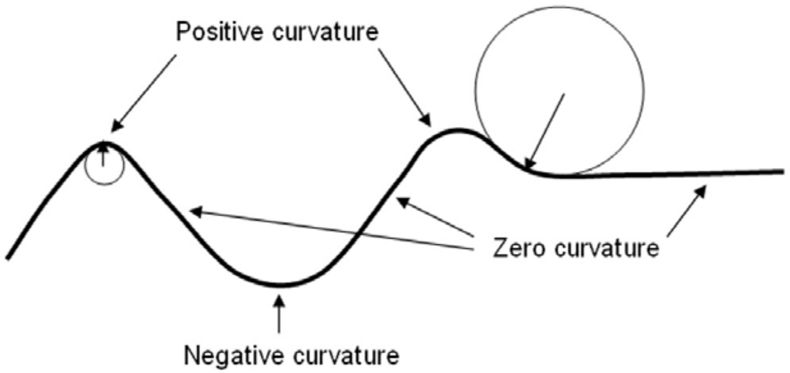
- UAVs(or other robots) can follow a path, which is designed by previous path planner, with relatively slow speed.

- Piecewise linear paths are generated by RRT, RRT*, etc.



◆ Backgrounds

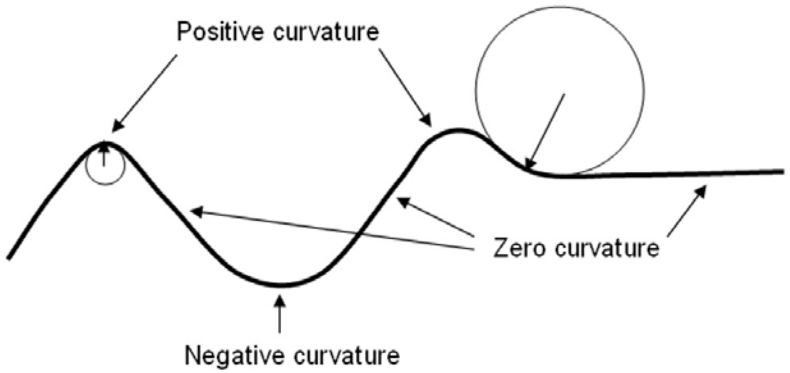
- **Curvature**



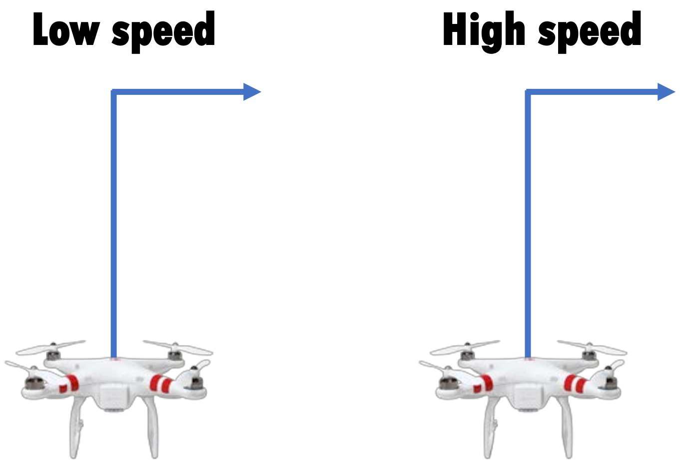
$$\kappa = \frac{\left| f''(x) \right|}{\left(1+\left[f'(x)\right]^2\right)^{\frac{3}{2}}}$$

◆ Backgrounds

- **Curvature**



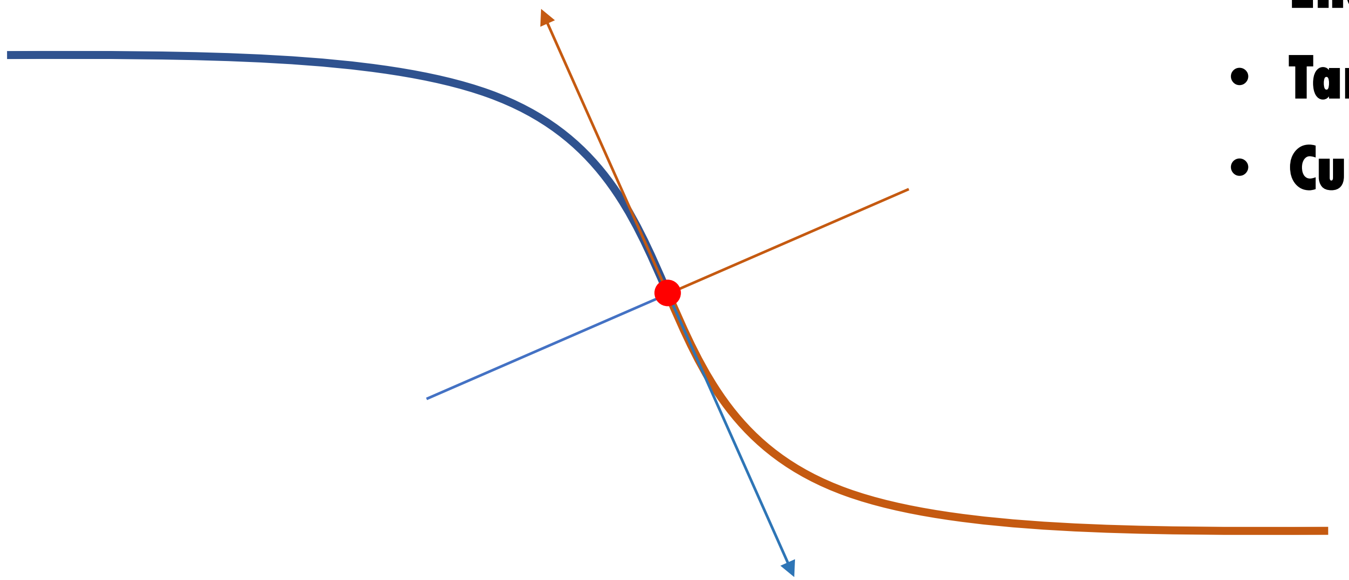
$$\kappa = \frac{\left| f''(x) \right|}{\left(1 + \left[f'(x) \right]^2 \right)^{\frac{3}{2}}}$$



- **Why is the curvature important?**
  - **Non-holonomic robots can't go through piecewise linear path with high speed**

Backgrounds

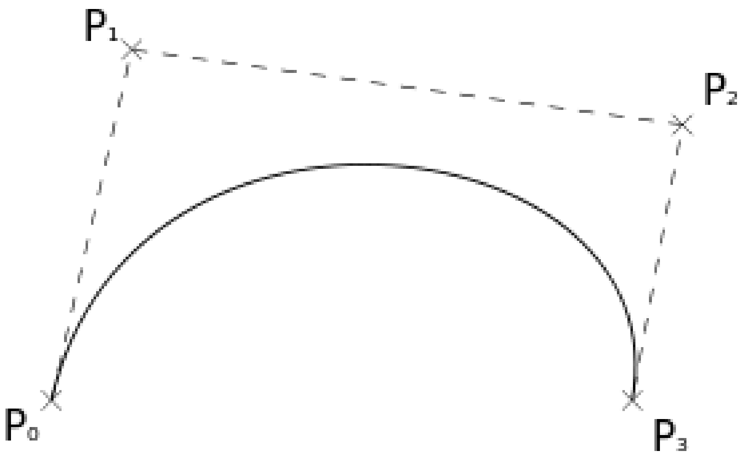
- G_2-Continuity



- End point
- Tangent
- Curvature radius

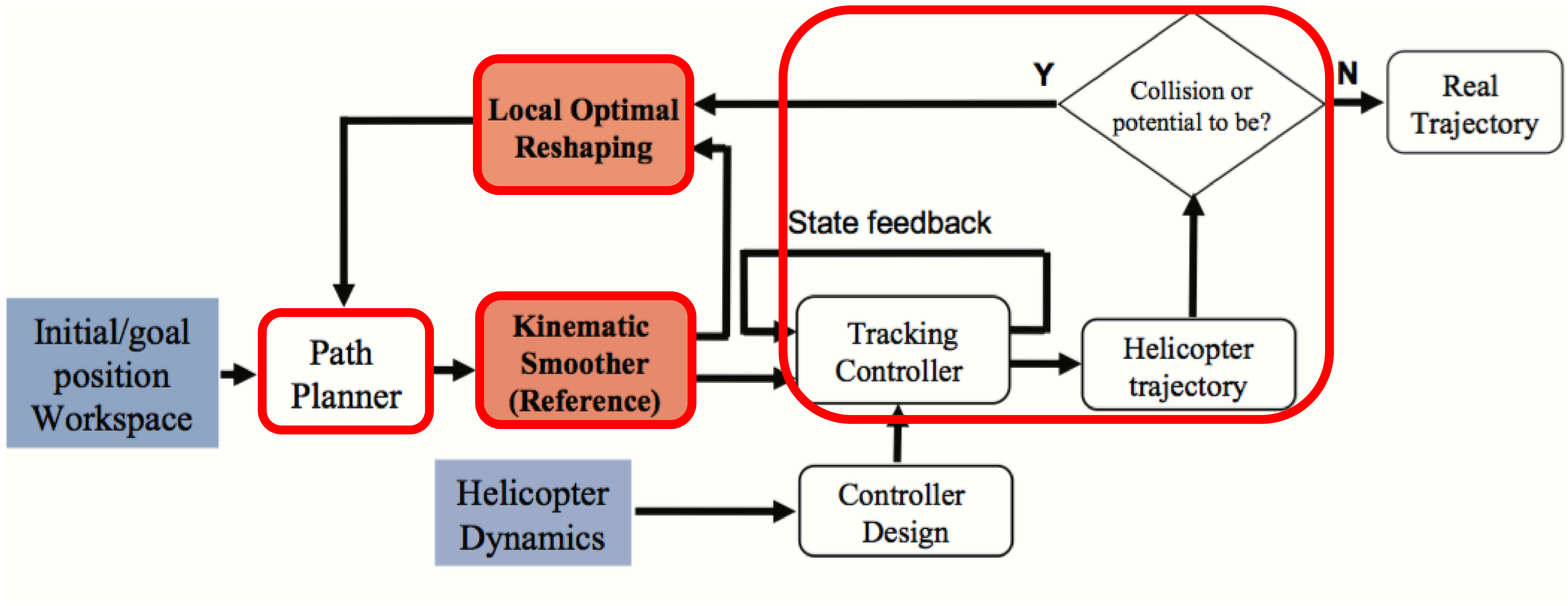
Backgrounds

- Bezier curve
  - Using Bernstein polynomial
  - N-1 order Bezier curve with N points
  - Continuous curvature at joint of two curves



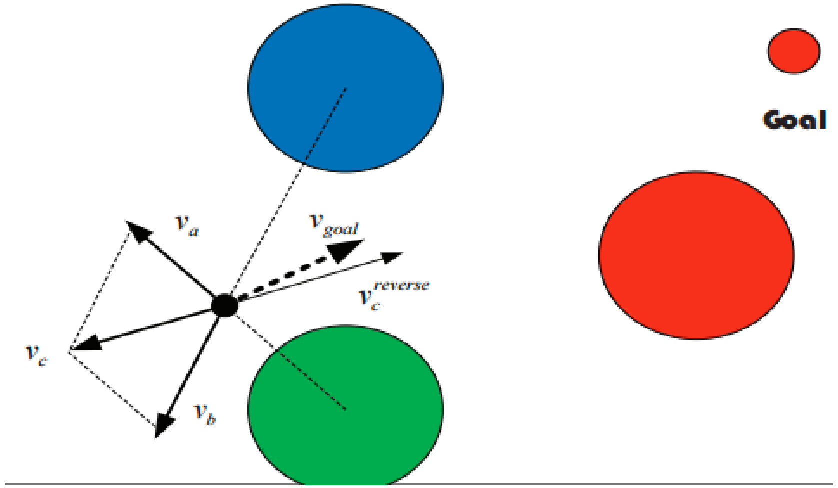
$$\mathbf{B}(t) = \sum_{i=0}^{n} \binom{n}{i} (1-t)^{n-i} t^i \mathbf{P}_i \qquad 0 \leq t \leq 1$$

Framework

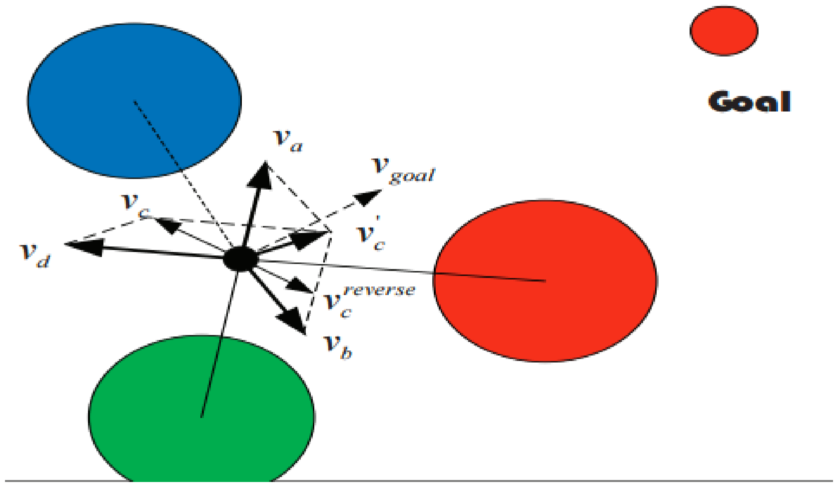

Local Optimal Reshaping
Y
Collision or potential to be?
N
Real Trajectory
State feedback
Initial/goal position Workspace
Path Planner
Kinematic Smoother (Reference)
Tracking Controller
Helicopter trajectory
Helicopter Dynamics
Controller Design

◆ Framework

- **Path planner : Guiding Attraction based Random Tree(GART)**
  - **Attraction to the goal & Repulsion by the obstacles**



(a) Two obstacles situation



(b) Three obstacles situation

◆ Methods

- Bezier curve based path smoothing
- Dangerous region finding
- Local optimal reshaping

Methods – Bezier curve based path smoothing

$$P_{[t_0,t_1]}(t) = \sum_{i=0}^{6} B_i^6(t) P_i$$

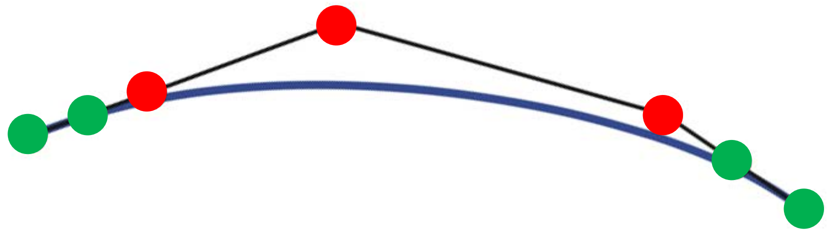
$$B_i^6(t) = \begin{bmatrix} 6 \\ i \end{bmatrix} \left(\frac{t_1 - t}{t_1 - t_0}\right)^{6-i} \left(\frac{t - t_0}{t_1 - t_0}\right)^{i}, i \in \{0, 1, ..., 6\}$$

$$K(t) = \frac{1}{R(t)} = \frac{x(\ddot{t})y(\dot{t}) - y(\ddot{t})x(\dot{t})}{(x(\dot{t})^2 + y(\dot{t})^2)^{3/2}}$$

Six-order → 7 points

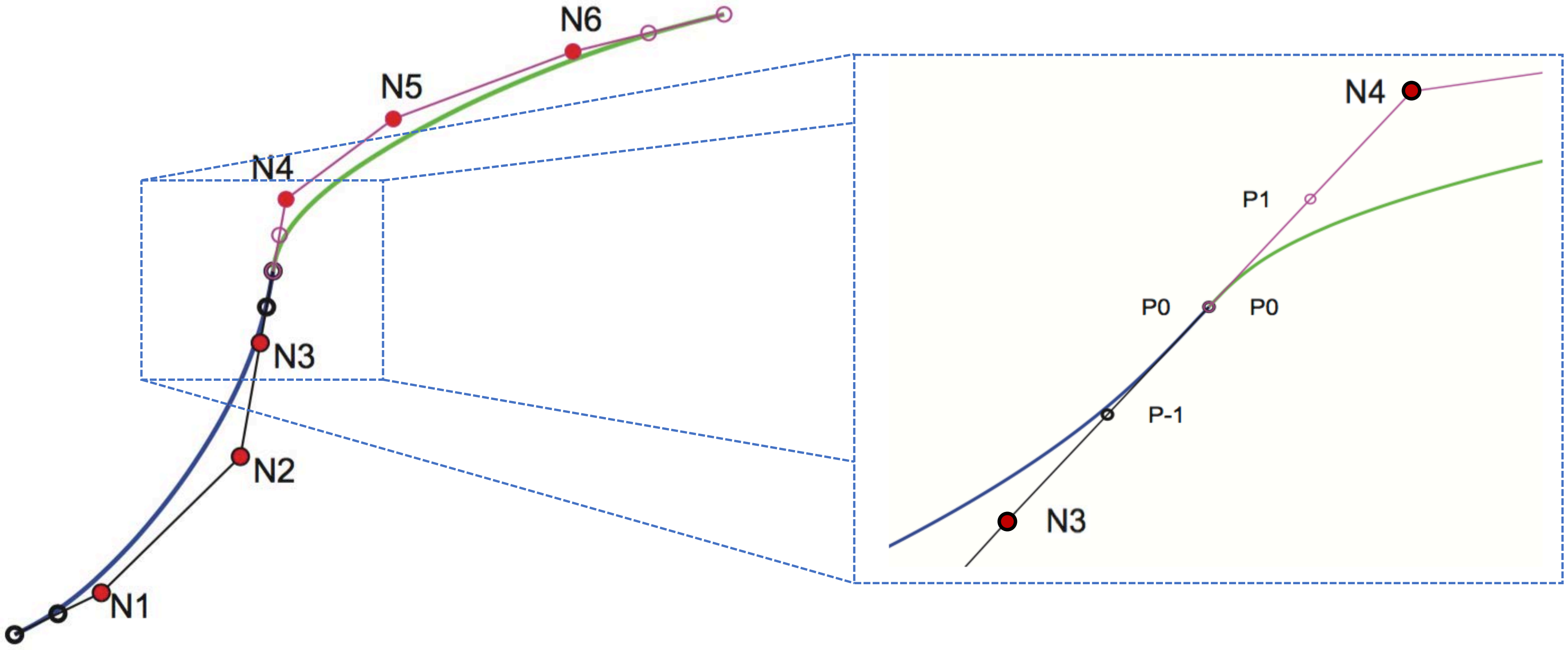
From path planner

From interpolation

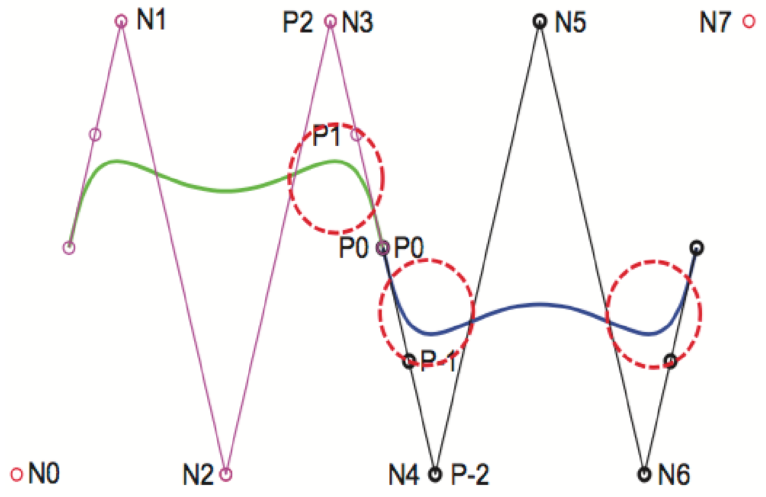


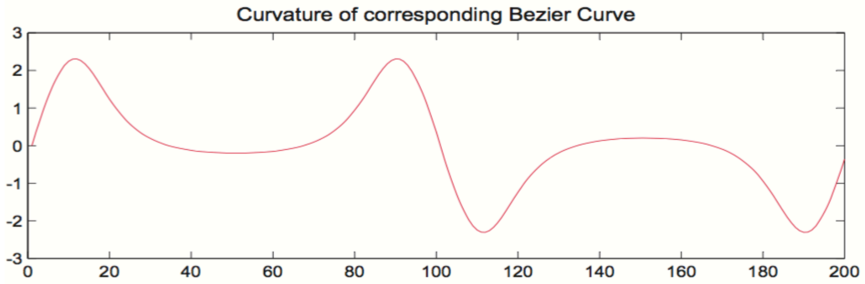
◆ Methods – Bezier curve based path smoothing

- How can we get interpolation points?

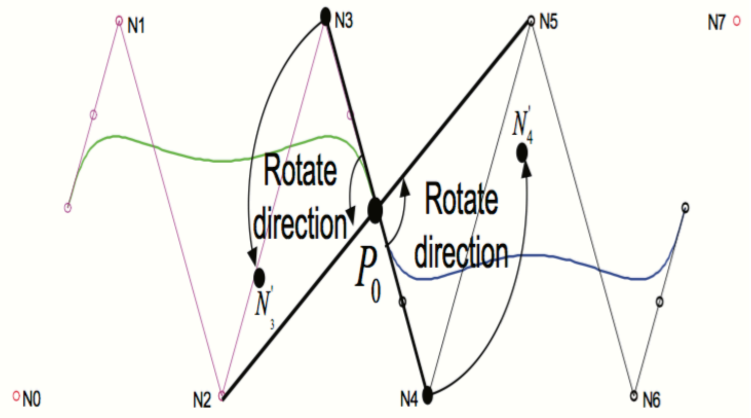


Methods – Bezier curve based path smoothing





- **Tuning Rotation(TR)**
  - **Turning adjacent node until smooth enough**
  - **Making the curve be consistent**



◆ Methods – Dangerous region finding

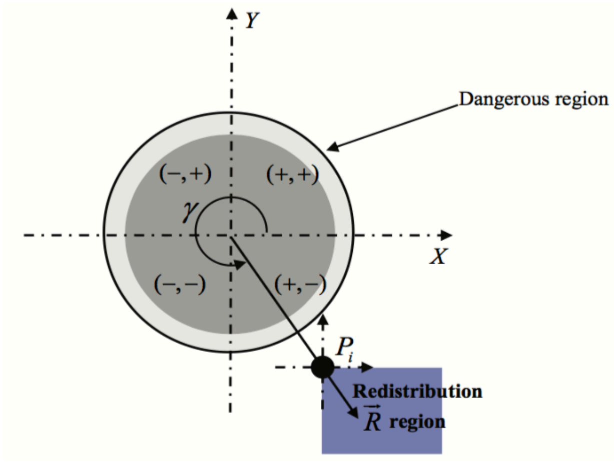
- "UAV simulations with dynamics show that the dangerous region"

- Performing fast simulation

- Obtaining dangerous regions (collision-expected)

◆ Methods – Local optimal reshaping

- **Nodes near dangerous region should be reshaped**



$$J_{cost} = \int_0^1 \sqrt{dx^2 + dy^2}dt + \int_0^1 \left(\frac{\dot{x}\dddot{y} + \dot{y}\dddot{x}}{(\dot{x}^2 + \dot{y}^2)^{3/2}} + \frac{-3 \cdot (\dot{x}\ddot{y} + \dot{y}\ddot{x})(\dot{x}\ddot{x} + \dot{y}\ddot{y})}{(\dot{x}^2 + \dot{y}^2)^{3/2}} \right)$$

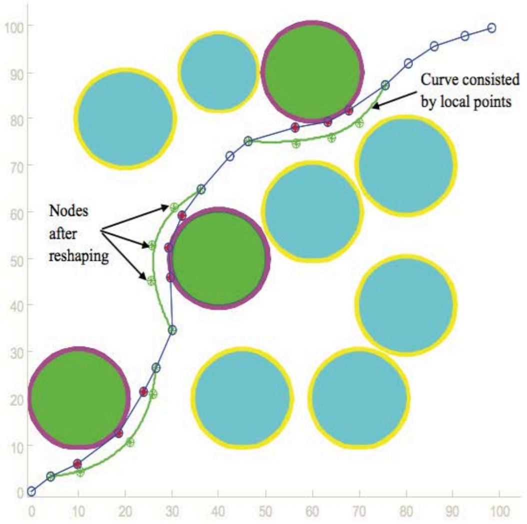
$$\begin{cases} \sqrt{(x - x_j)^2 + (y - y_j)^2} > r_j + d_{safe} & (1) \\ P_i(1,t) \cdot sgn[cos(atan(\frac{P_i(2) - y_j}{P_i(1) - x_j}))] > P_i(1) & (2) \\ P_i(2,t) \cdot sgn[sin(atan(\frac{P_i(2) - y_j}{P_i(1) - x_j}))] > P_i(2) & (3) \\ P_t = \Sigma_{i=0}^{n} \begin{bmatrix} n \\ i \end{bmatrix} \cdot t^i \cdot (1-t)^{n-1} P(i) & (4) \end{cases}$$

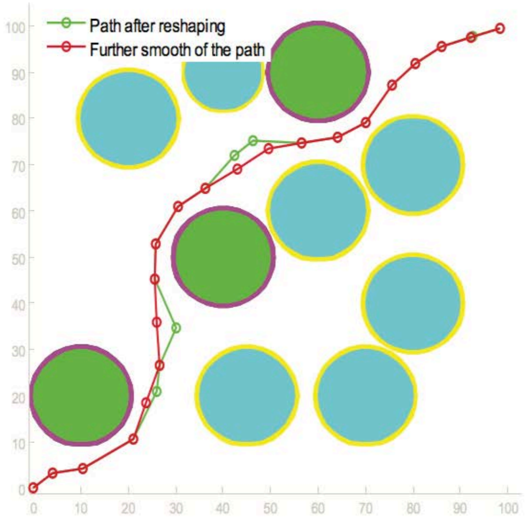
... from center of object

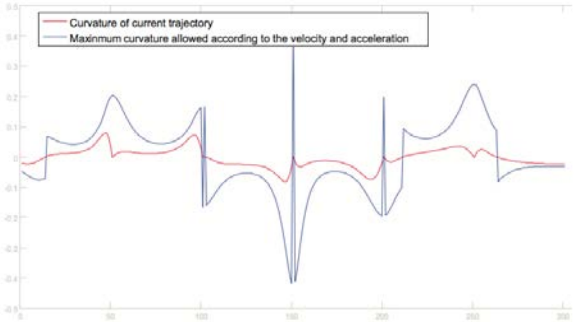
$d_{safe} = 4\text{m}$

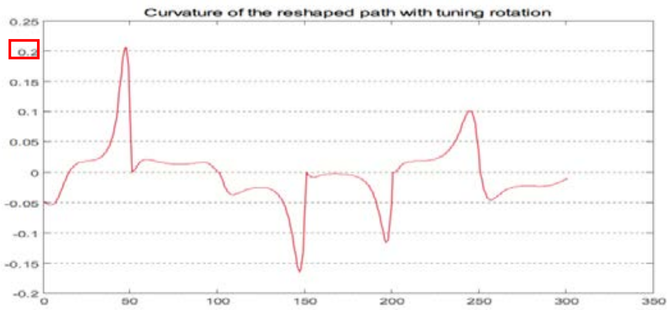
◆ Result

- **Curvature within maximum curvature after smoothing and reshaping**
- **Not enough to their target curvature 0.1**



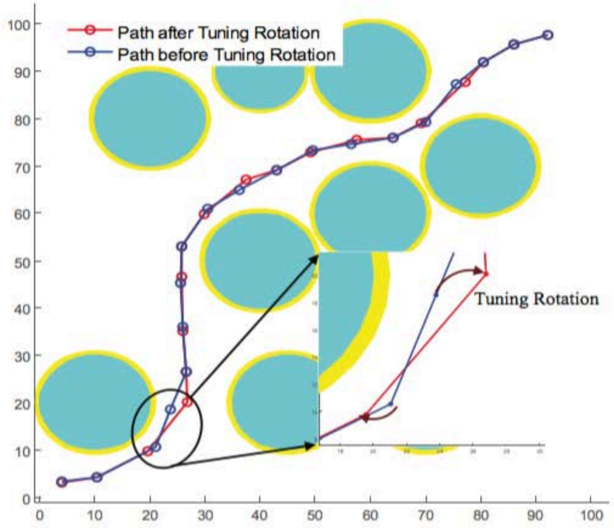


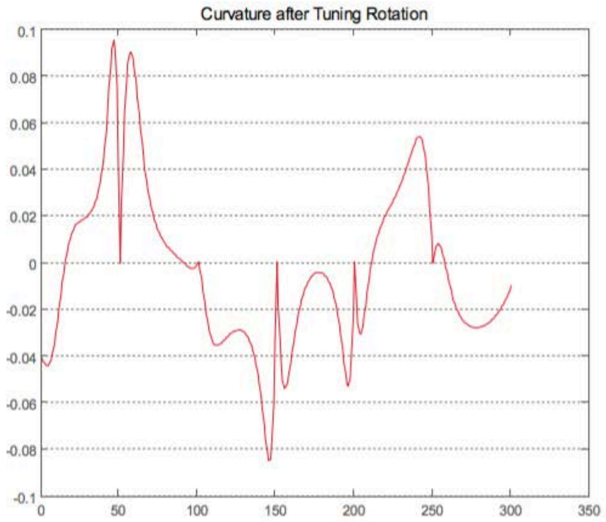




◆ Result

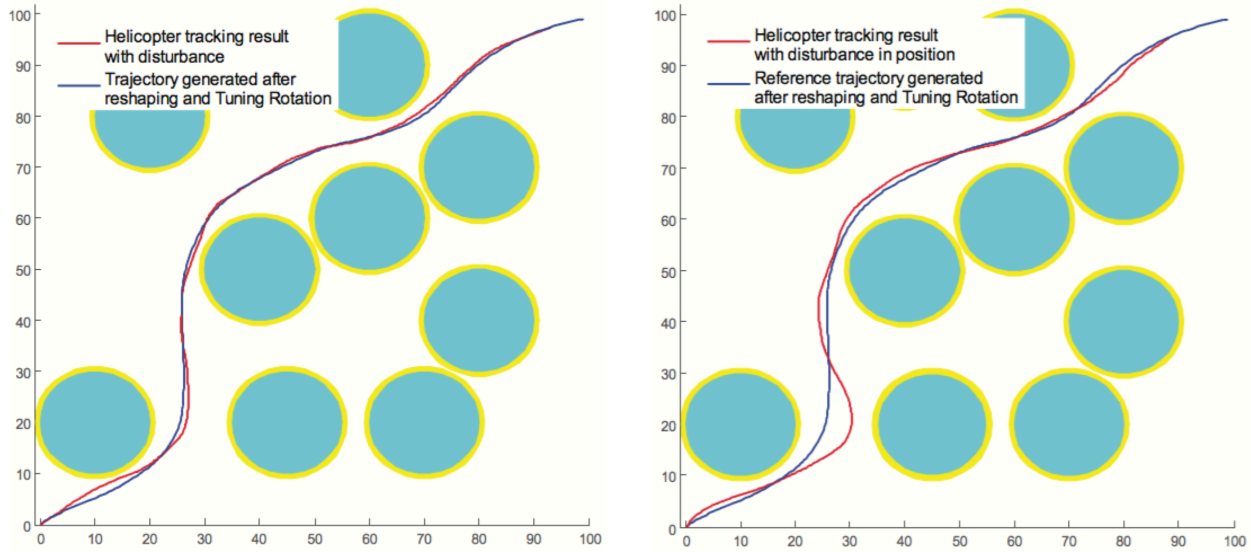
- **After Tuning Rotation, curvature becomes lower than 0.1**





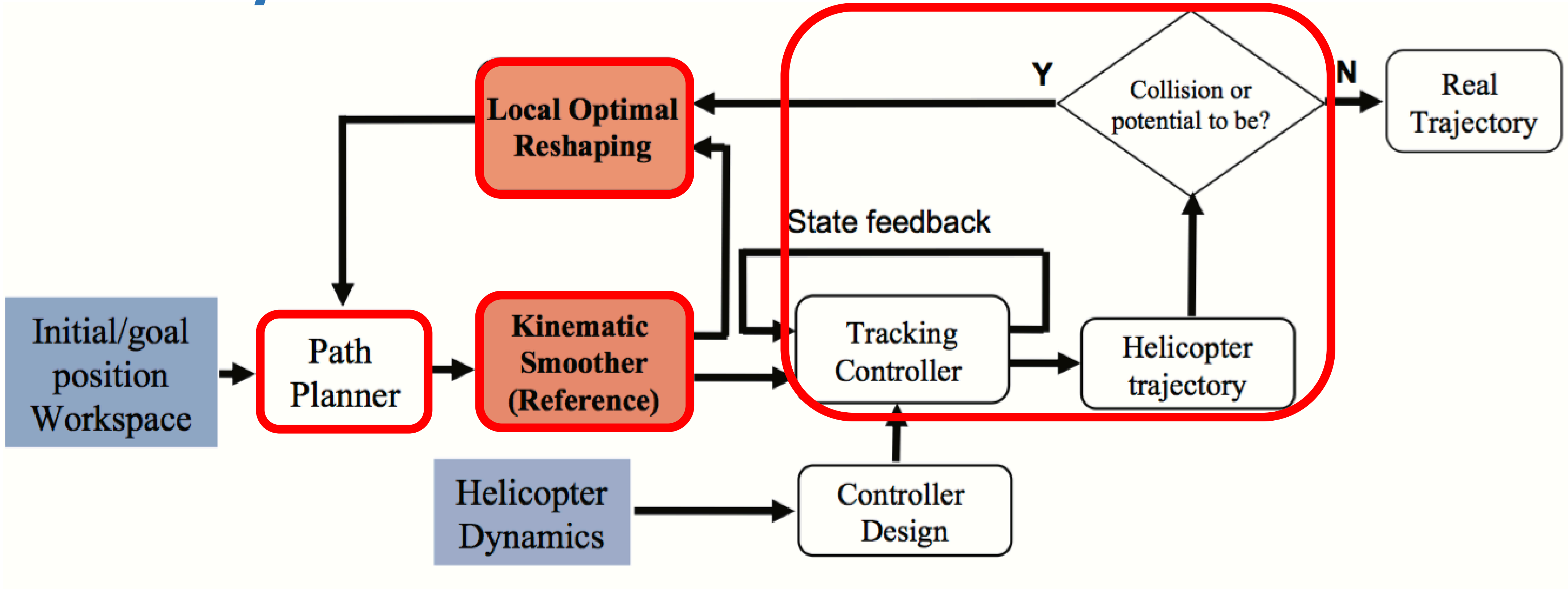
◆ Result

- **With speed disturbance 0.2m/s magnitude of WGN**



(a) Position tracking result. (b) Speed tracking result.

◆ Summary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◆ Limitation

- No mention about computational time
- No dynamics
- No difficult obstacles

QnA

THANK YOU

References

- *Generation of Dynamically Feasible and Collision Free Trajectory by Applying Six-order Bezier Curve and Local Optimal Reshaping* (IROS 2015)
- *Guiding attraction based random tree path planning under uncertainty: Dedicate for UAV* (IROS 2014)